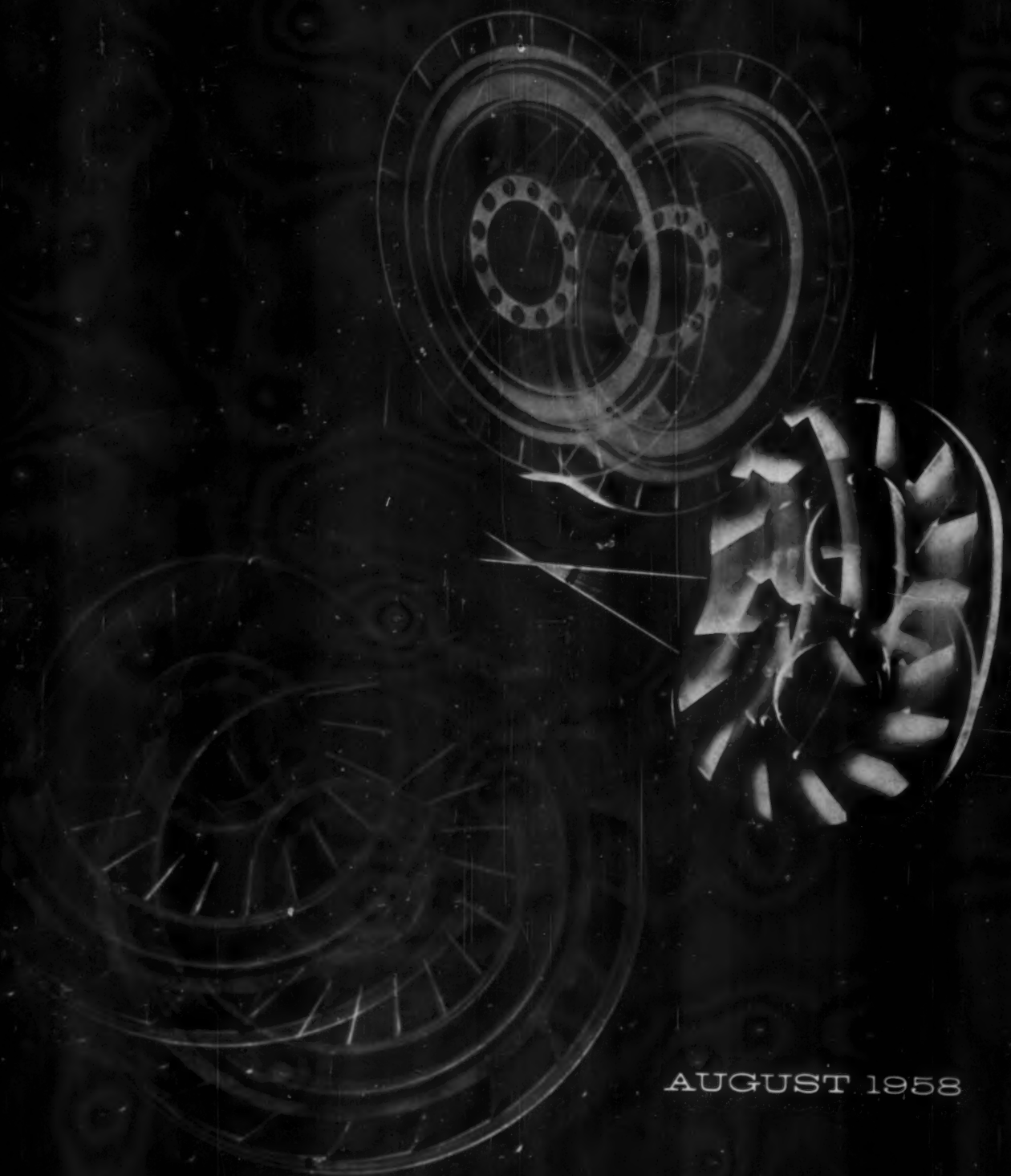
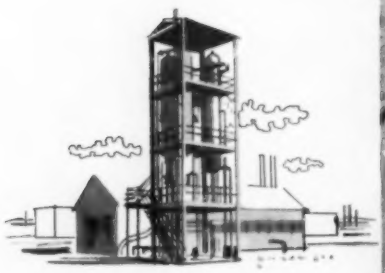
Metal Progress



AUGUST 1958

Pilot plant reactor shell *after 2000 hours service. Note corrosion on stainless steel shell and flange, while titanium liner shows no corrosion effects. Right: Titanium dip-tube after 2000 hours operation remains free of corrosion damage.*



In high-temperature nitric acid service...

TITANIUM WINS TOUGH 2000-HOUR CORROSION TEST

A large petrochemical company recently tested titanium versus other metals in high-temperature nitric acid service. 6% to 10% concentrations were handled in a pilot plant reactor at temperatures between 300° to 400°F.

Above you see dramatic proof of titanium's performance in this punishing service. After 2000 hours, the reactor's titanium liner and dip-tube showed no corrosion effects, while the stainless steel shell and flanges were badly corroded.

Further corrosion-rate tests were made by immersing test coupons of various metals in the reactor for 40 hours. Again, test results proved titanium's outstanding corrosion resistance (see chart at right).

Want more information? Write for bulletin on Corrosion Resistant Properties of Titanium.

CORROSION RATE TEST
Conditions: 375° F, 300 psig, 6% nitric acid

Material	Corrosion Rate mils/yr
Titanium	nil
347 stainless steel	59
304 stainless steel	170
310 stainless steel	274
410 stainless steel	402
309 stainless steel	485
Nickel-Chrome Alloy	20,500

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August 1958 . . . Volume 74, No. 2

Cover design by Jean Philippe Charbonnier, staff artist for the French magazine, *Réalités*

Feature on Vacuum Melted Alloys

Vacuum Melting Today, Staff Report 94

Vacuum is being increasingly used in processing steels and superalloys for today's most stringent applications. Appreciable amounts of active elements can be added as alloying agents; gases and inclusions are reduced. The user has available a number of vacuum-produced alloys and more are in the offing. (C25, C5, D9, 1-73)*

Production of Discaloy by Vacuum Arc Melting, by D. R. Carnahan 100

Problems solved during development of the commercial process for consumable arc melting of this high-temperature alloy. (C5h, 1-73, SGA-h)

A User Looks at Cleanliness of Vacuum-Melted Alloys, by Donald E. Nulk 103

The problem of "how clean is clean" is becoming more acute with the development of new superalloys containing increased amounts of reactive elements. Carbides and nonmetallic inclusions interfere with fabrication, influence service conditions and decrease the effectiveness of the alloy from the standpoint of chemical balance. Methods used to measure cleanliness are modified A.S.T.M. inclusion rating, frequency/severity rating and metallographic classification. (N12, N3, M27, C25, SGA-h, 9-69)

Vacuum Degassing 142

Digest of "Vacuum Casting of Steel", by John N. Hornak and M. A. Orehoski, tells of design, construction and operation of equipment for casting large ingots for turbine rotors with less than 1.5 ppm. hydrogen.

Vacuum Degassing at Bethlehem 146

Digest of "Vacuum Pouring of Ingots for Heavy Forgings" by J. H. Stoll, describes two 250-ton units put into production in 1957.

Data Sheet

Vacuum Melted Alloys 96-B

Data from 17 manufacturers showing grades or trade names, compositions and uses.

Engineering Articles

A Lesson in Fabricating Nuclear Parts, Staff Report 68

Metalworking techniques developed for zirconium and hafnium reactor components. Welding is in a dry box, heat treating is in a vacuum; forming is done hot. Surface treatment and testing are special, too. (T11, G-general, J-general, K-general; Zr, Hf)

Molybdenum Is Here To Stay, by J. L. McCloud 75

Molybdenum is pre-eminent among metals for high-temperature uses and is solidly entrenched in the electronics industry and for missile parts whose working life is very short. Protective coatings have been perfected so gas turbine blades can run at 2000° F. (Q-general, 2-62, T24c, T1, 17-57; Mo)

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Metal Progress

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Improved Methods of Deep Drawing, by Our Special Correspondent 84

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W-545 ... A Better Turbine Disk Alloy, by J. T. Brown 87

A new iron-base turbine disk alloy has a good combination of high-temperature stress-rupture strength and ductility, and low-temperature tensile strength. Boron increases the inherent ductility of the present austenitic precipitation hardening alloys. Further strengthening is provided by titanium. (Q-general, T7h, 17-57, 2-62; Fe, SGA-h)

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Electrolytic salt bath cleaning and centrifugal casting together can produce strong, long-lived bearings. (T7d, L12n, S14; CI, Sn, Pb)

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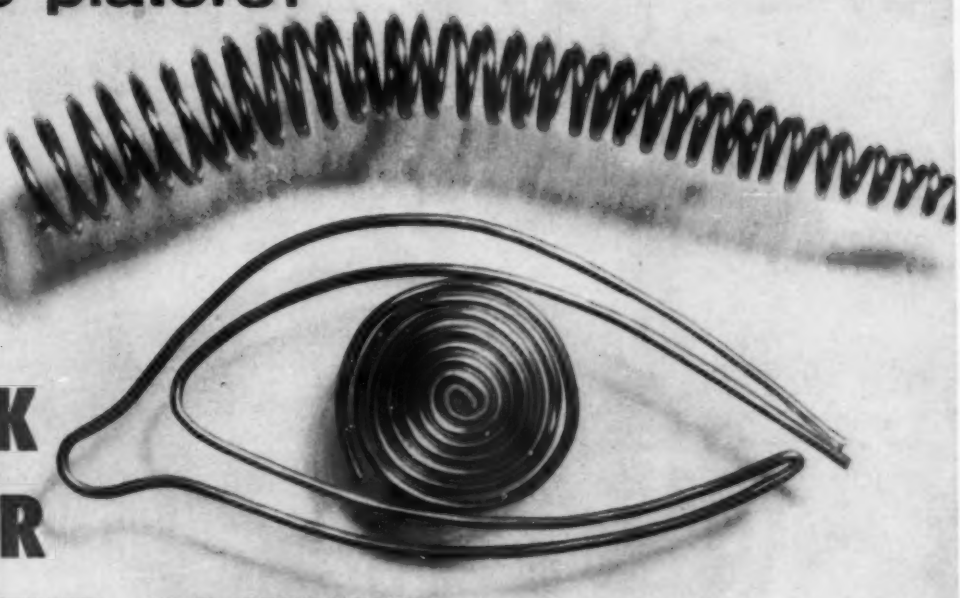

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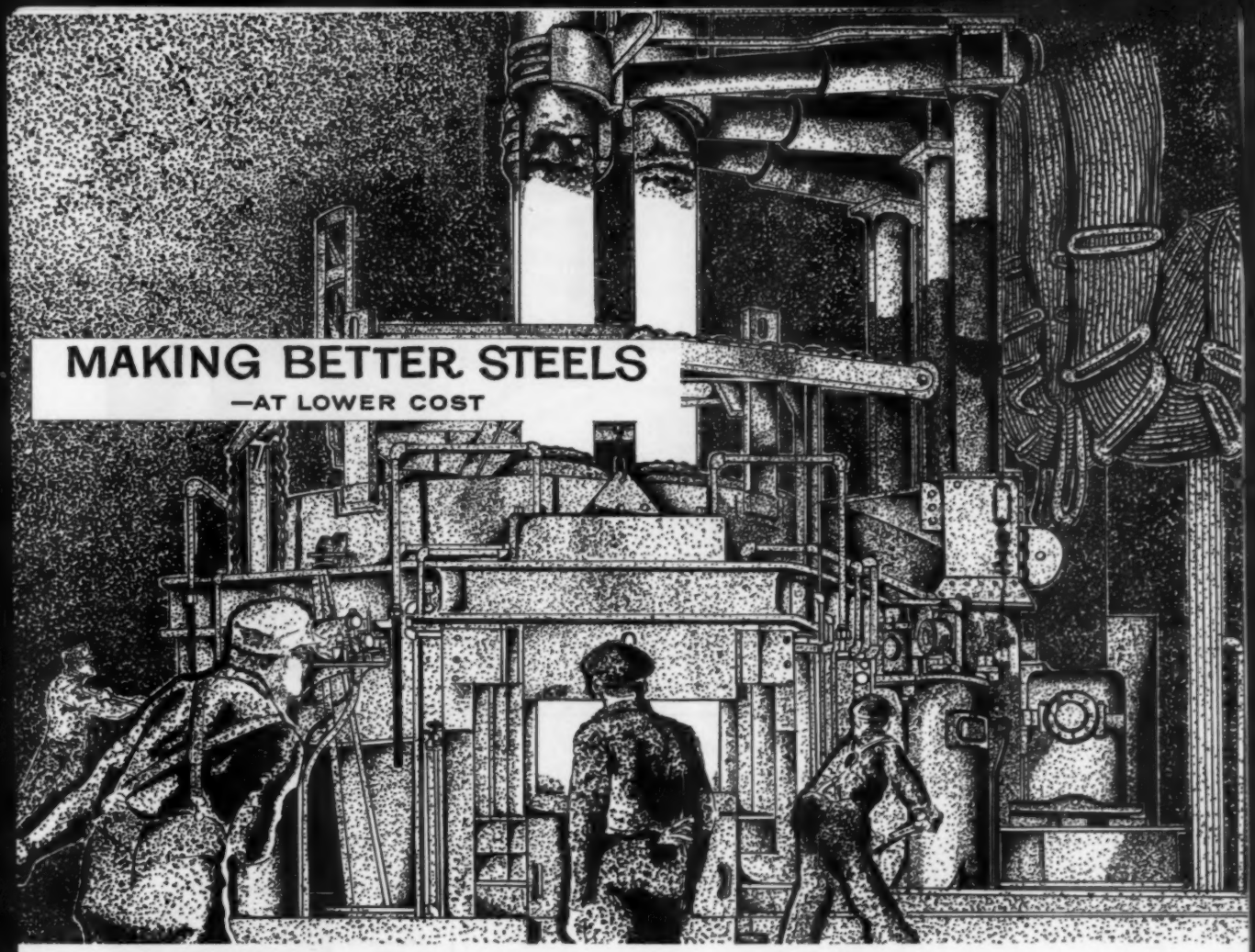

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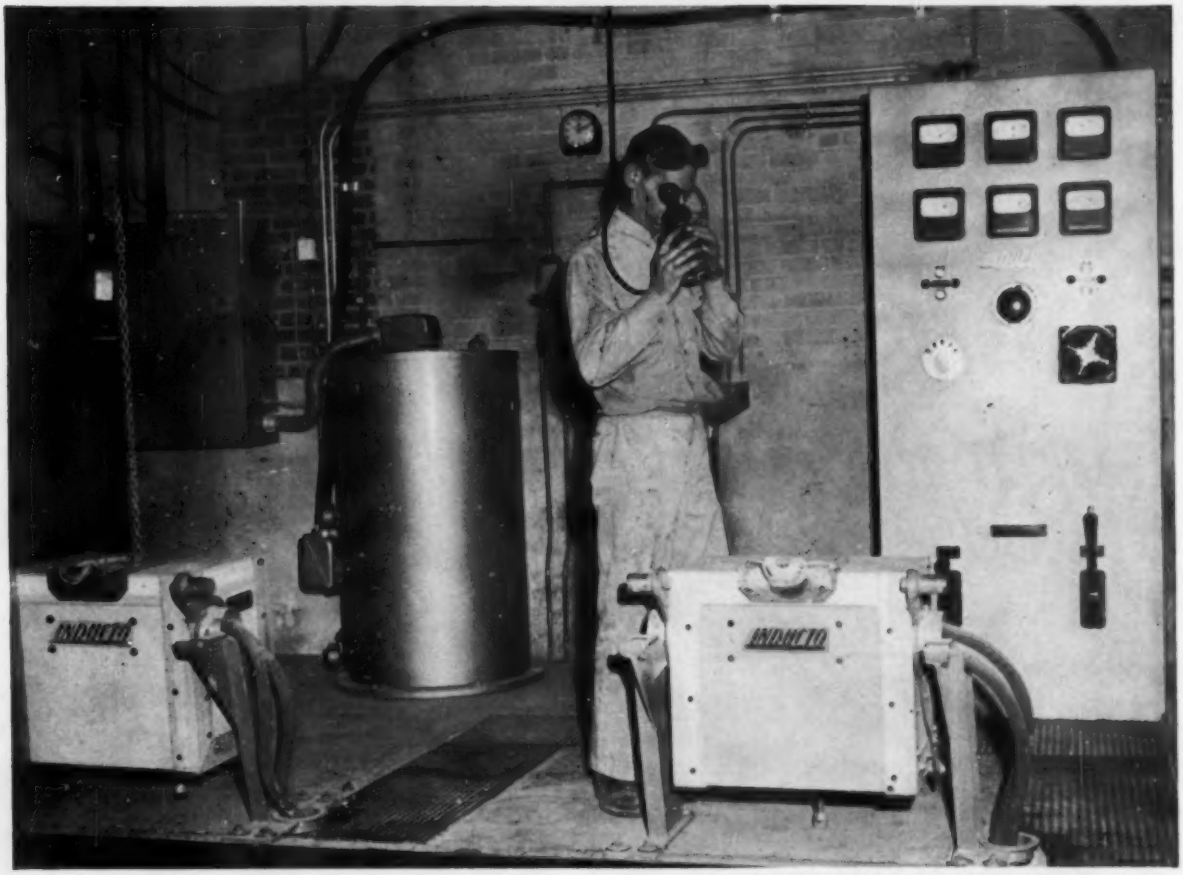

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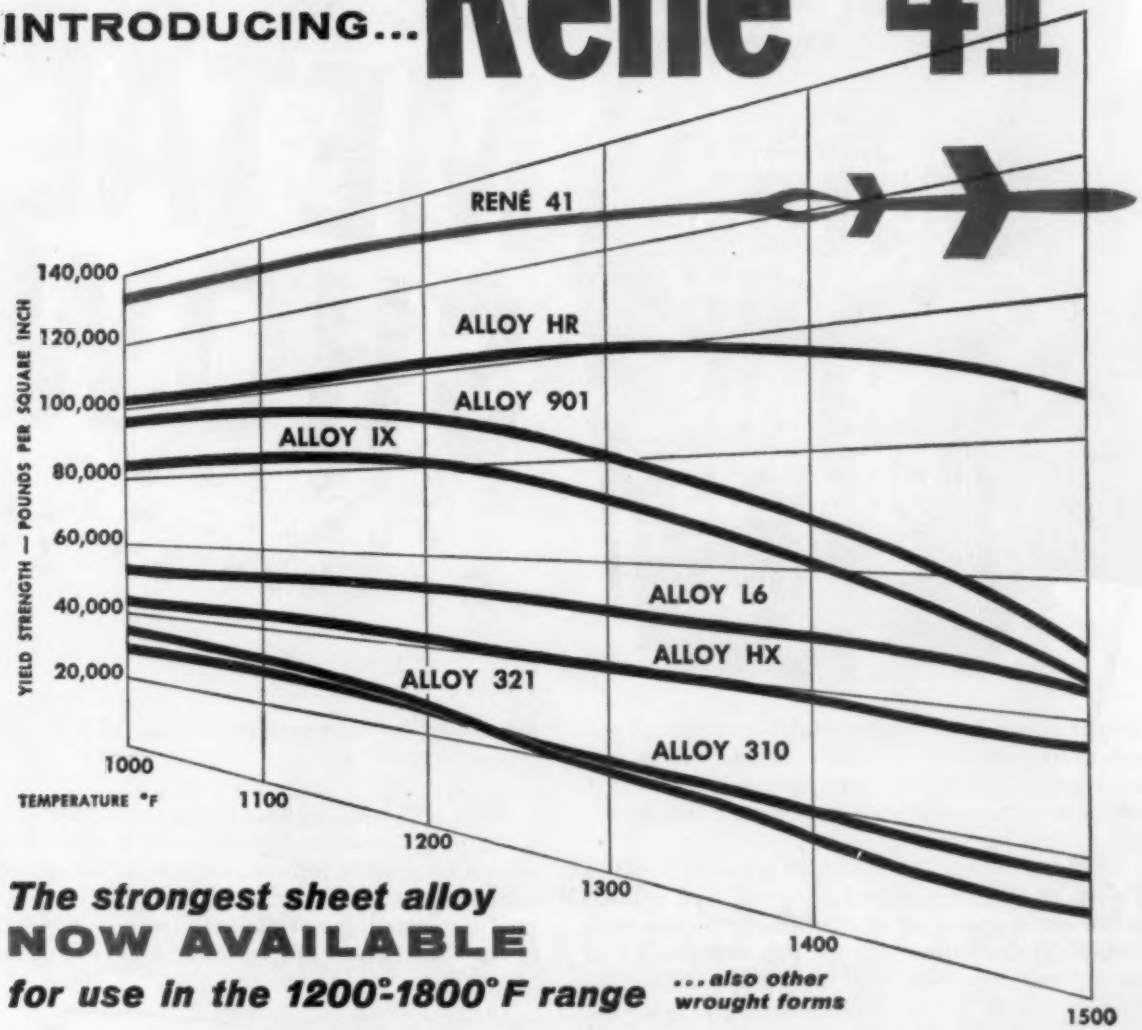

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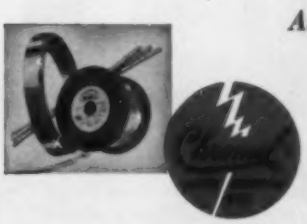

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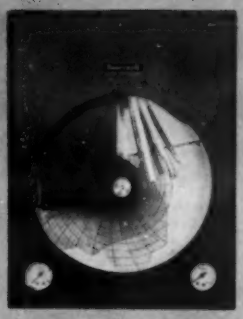

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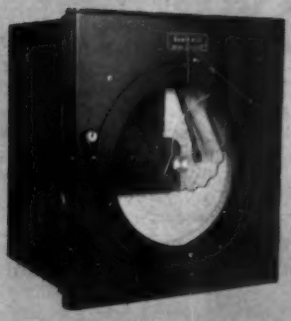

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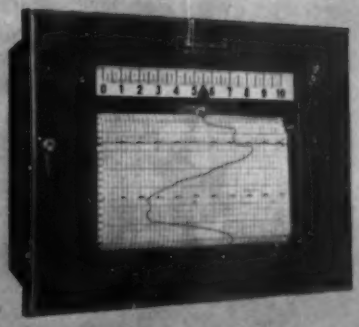

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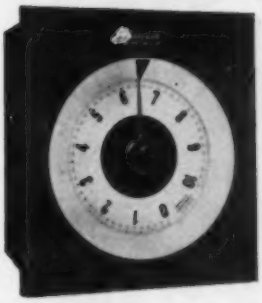

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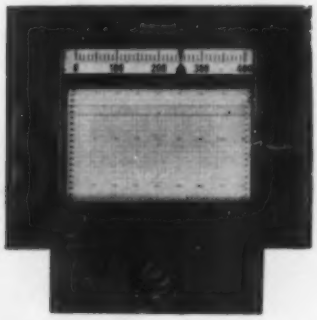

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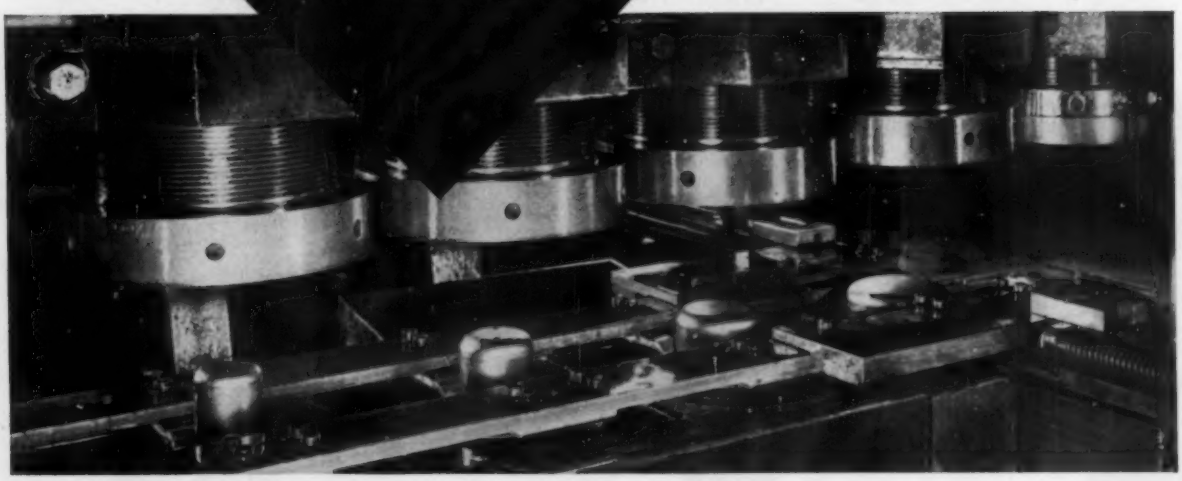


To deliver uniform performance between grinds, a drawing or blanking die has to be hard and tough through its whole thickness.

And no matter how well it is designed and heat treated, it can only be as uniform through the center as the bar you make it from . . . and the bar can only be as uniform as the ingot from which it is rolled.

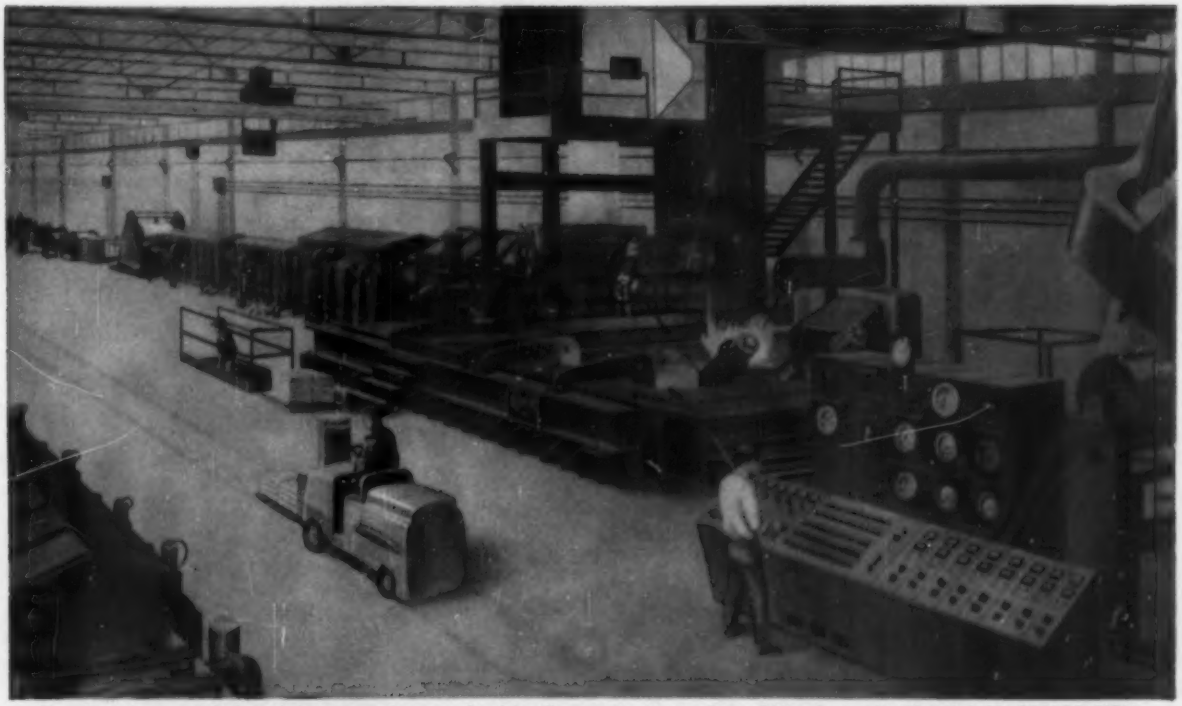
That's why, when you make a die from Carpenter MEL-TROL air hardening die steels—such as No. 484 and No. 610 —you *know* you're going to get predictable performance. The high quality of MEL-TROL die steels is guarded by a system of the most advanced and accurate quality controls ever used in steel making.

And an exclusive Carpenter-patented mold produces ingots with greater uniformity through the center than any others made on a production basis today.

Why don't you try Carpenter MEL-TROL quality tool and die steels? Call your Carpenter representative and place your order today.

Carpenter STEEL

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Alloy Tube Division, Union, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.
Webb Wire Division, New Brunswick, N. J.



The above is a partial view of the two continuous galvanizing lines at the Martins Ferry, Ohio, plant of WHEELING STEEL CORPORATION. Both lines use AJAX 60 cycle induction galvanizing furnaces and zinc premelt furnaces. The main galvanizing furnace shown holds 175 tons of zinc, is rated 2000 kw, and produces over 40 tons per hour at speeds in excess of 300 feet per minute. These continuous galvanizing lines produce WHEELING's patented SOFTITE sheet.

60 Cycle induction galvanizing

has progressed from small beginnings a few years ago to a present capacity of well over **one million tons per year.**

Here is an entirely new approach to an old art:

- A refractory lined hearth in place of the iron kettle eliminates kettle replacement and iron pickup, drastically reduces dross formation.
- Temperature control is precise, lag free, holds the melt at ideal galvanizing temperature at all times.
- Gentle electromagnetic circulation facilitates alloy additions, keeps alloy uniform throughout the melt.
- Clean and cool working conditions for hand dipping or continuous operations.

All these factors help to produce a galvanized coating of consistent superior quality and to attain high production at lowest unit costs.

MAY WE HAVE YOUR INQUIRY?

AJAX USA

ENGINEERING CORPORATION

TRENTON 7, NEW JERSEY

60 CYCLE INDUCTION MELTING

Associated Companies: Ajax Electrothermic Corporation Ajax Electric Company

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(ALL THE FACTS AT NO COST OR OBLIGATION)

☐ TOOL STEELS

An up-to-the-minute course covering the development of tool steels, their selection and properties. Authors George A. Roberts, Vice President, Technology, Vanadium-Alloys Steel Company, and John C. Hamaker, Jr., Manager of Research, Vanadium-Alloys Steel Company, offer an expert analysis of processes, testing techniques (both mechanical and structural), heat treatment and classification of tool steels. Also includes details on the purpose and effect of alloying additions, water hardening tool steels, and both cold and hot work die steels.

☐ MAGNESIUM

Fundamentals and latest developments in the technology of magnesium. Ralph G. Gillespie, Technical Advisor, Brooks & Perkins, Inc., presents authoritative, up-to-date information on the entire magnesium industry from extraction, melting, alloying, and casting through manufacture of finished products and economic considerations. Also includes details on machining, joining, corrosion, protective finishes and testing methods.

☐ COPPER, BRASS AND BRONZE

Dr. Owen W. Ellis, Consultant, former Director of Department of Engineering and Metallurgy, Ontario Research Foundation, covers the fundamentals and latest developments in the technology of the copper industry and offers a comprehensive survey of copper alloy fabrication by all the hot and cold working methods in general use today. Detailed information presented on ore concentration, smelting and refining, alloying and mechanical properties, machining and joining, and corrosion resistance.

☐ ARC WELDING

Emphasis is placed on technical problems involved in producing quality welds in the entire range of engineering alloys including low carbon steel, low and medium alloy steel, high alloy steels, copper, aluminum, magnesium, titanium, nickel, and their alloys. Presents surveys covering weld design, quality control and test procedures, and weldability. Prepared by Clarence E. Jackson, Staff Engineer, Linde Air Products Company.

☐ FUNDAMENTALS OF FERROUS METALLURGY

Presents a comprehensive survey of the fundamental principles of ferrous metallurgy. 15 lessons include instruction on the iron blast furnace, steelmaking, hot and cold working of steels, structure of iron and steel, physical and nondestructive testing, heat treatment, and surface treatment. An overall picture of both the process and physical metallurgy of iron and steel.

☐ IRON BLAST FURNACE OPERATIONS

An analysis of the blast furnace process based on authoritative research, by Charles E. Agnew, Consultant, former Superintendent of Furnaces, Alan Wood Steel Company. Compares practice data with actual furnace operations. Excellent as a guide for both technical and nontechnical personnel, providing valuable information for anyone concerned with, responsible for, or interested in the operation of an iron blast furnace.

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USS "T-1" Steel can be flame-cut, welded, formed, sheared, punched, machined or forged.

How to **beef-up** your equipment without adding fat

Build it stronger, tougher and lighter with USS "T-1" Steel. This remarkable steel was developed especially to meet the needs for bigger tools, stronger equipment, larger yet less massive structures.

USS "T-1" Steel is a low carbon, quenched and tempered constructional alloy steel combining weldability and formability with exceptional strength and toughness. Because of its high yield strength (100,000 psi minimum) you can cut weight safely—in actual applications, as much as 25% to 50% weight reductions have been achieved.

Total costs can frequently be reduced, too. In applications such as heavy machinery, rotating parts, pressure vessels and bridge members, steel costs can be lowered by reduction in cross section and substantial savings experienced in welding, maintenance, freight and erection costs.

Also, in equipment subjected to impact abrasion, USS "T-1" Steel pays off. Users report service life increases ranging from 25% to 100%—or more. Power shovel buckets, bulldozer blades, coal and ore bins . . . all cost less in the end when made of "T-1" Steel because they last longer, cost less to maintain.

Write for free book. The many advantages, applications and cost-saving features of this versatile steel are completely described in our book USS "T-1." United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS and "T-1" are registered trademarks

United States Steel Corporation – Pittsburgh
Columbia-Geneva Steel – San Francisco
Tennessee Coal & Iron – Fairfield, Alabama
United States Steel Supply – Steel Service Centers
United States Steel Export Company

USS **United States Steel**

Why cyclotron magnet frames are made from forgings

Man is in a desperate race to learn more about magnetics. One famous acres-big cyclotron could be reduced to the size of a steamer trunk if they could only find a way to increase the magnetic field strength by 20 times. And already we see evidence that very strong magnetic fields may hold the secret to one of man's most sought-after dreams: sustained nuclear fusion power generation.

But when you double the strength of a magnetic field, the energy density or pressure increases *fourfold*. A not-uncommon 50,000 gauss magnetic field exerts a pressure of about 1,400 psi; but other laboratory experiments have already created fields of 1½ million gauss for a few microseconds, and they confidently expect to hit *10 million* gauss before long!

To contain the fantastic forces, designers of very large electromagnets turn to high-quality forged steel parts, and they very often come to United States Steel to ask for USS Quality Forgings.

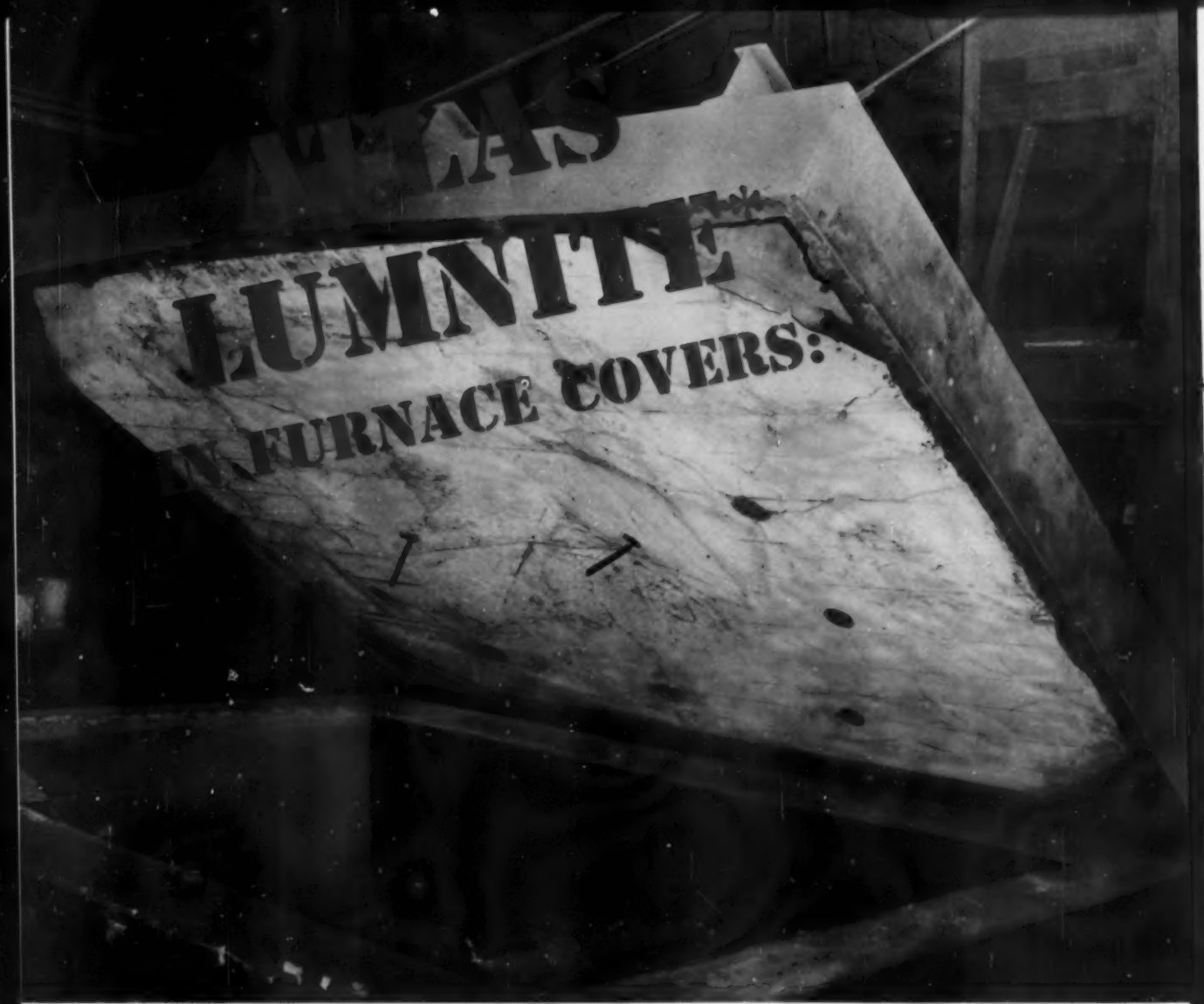
The picture shows a cyclotron electromagnet frame that will go into service at Oak Ridge National Laboratory, Oak Ridge, Tennessee. It is made from six USS Quality Forgings that total 193 tons including the two cylindrical pole pieces. The pole pieces are machined to a .005″ flatness, and are parallel to within .005″. These tolerances are essential for close control over the bombarding particle beam—which often operates at velocities which approach 50,000 miles *per second*. All six forgings were melted, forged, machined, heat-treated and inspected right at our Homestead Forgings Division, and we also furnished all dowels (4½″ in diameter), nuts, bolts and lifting eyes.

Many cyclotron and nuclear reactor parts are made from USS Quality Forgings because buyers have learned that they are made from the finest steel, on the most modern equipment, by the most skilled forging men in all the world. No matter what kind or size of USS Quality Forgings you buy, you get the advantage of these same facilities. Please address inquiries or requests for our free forgings booklet to United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

USS is a registered trademark

United States Steel Corporation – Pittsburgh
Columbia-Geneva Steel – San Francisco
Tennessee Coal & Iron – Fairfield, Alabama
United States Steel Export Company

USS United States Steel



To date, monolithic flat arch cover (refractory concrete made with LUMNITE calcium-aluminate cement) has provided 4 years' maintenance-free service in pit-type gas annealing furnace. Service Foundry Division, Avondale Marine Ways, Inc., New Orleans.

"...installation time cut in half...no maintenance...less heat loss,"

says Carl W. Goodgion, Chief Metallurgist, Service Foundry Division, Avondale Marine Ways, Inc.

- Refractory concrete (made with LUMNITE cement) resists extreme variations in temperature and repeated thermal shock – gives longer service life to furnace parts and linings.
- Installation is fast, easy, economical – concrete reaches service strength in 24 hours.

For maximum convenience, use castables made with LUMNITE cement. These are packaged mixtures, ready for use. Simply add water, mix and place. Made and distributed by leading manufacturers of refractories.

For literature on refractory concrete, write: Universal Atlas, 100 Park Avenue, New York 17, N. Y.

L-170

UNIVERSAL ATLAS CEMENTS

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Universal Atlas Cement Company

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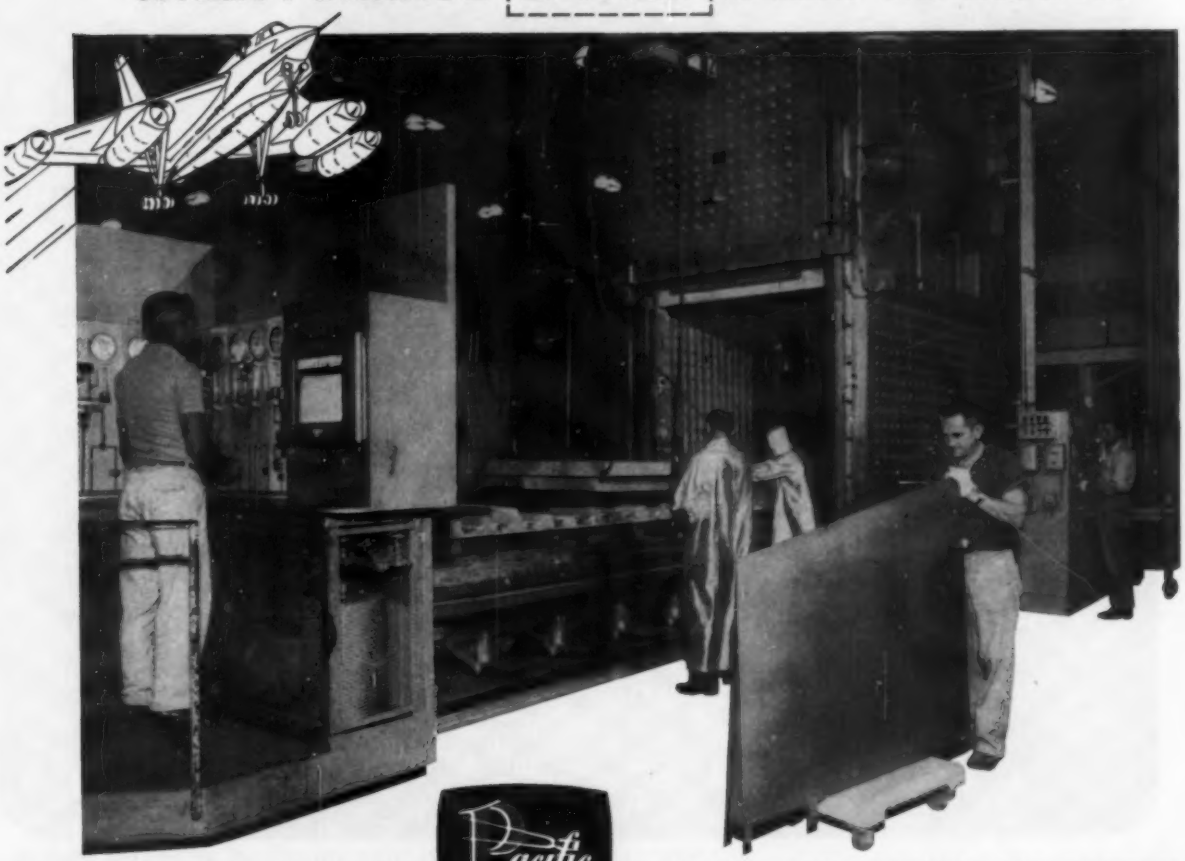
WHEN FURNACE DESIGN *REALLY* COUNTS . . .



ROHR AIRCRAFT TURNED TO Pacific TO BUILD THE LARGEST CAR-BOTTOM HIGH-TEMPERATURE, ATMOSPHERE-TIGHT BRAZING FURNACE OF ITS KIND!

For brazing all-metal sandwich structures used in the construction of Convair's new high speed B58 bomber – this huge Pacific car-bottom furnace puts what otherwise might be a difficult operation on a production basis. A wedge-shaped section of the honeycomb is shown in the right foreground of the above photograph.

The use of this material because of its high temperature weight-strength ratio necessitated the development of a large capacity high temperature furnace.

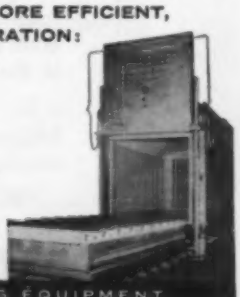
All the exacting requirements for honeycomb brazing are fully met, including extreme uniformity of temperature. The furnace is suitable for use with all-welded retorts and provision is made for vacuum and atmosphere lines from retort to external components. Loading and unloading is fast for a good production rate.

Pacific's long experience in brazing, and their extensive knowledge and appreciation of the problems encountered in this specialized process – helped Rohr Aircraft solve their brazing problems. This is but one of many special furnaces custom-designed and built by the Pacific Scientific Company where Pacific's advanced design and construction technique paid off in efficient, economical operation.

When furnace design *really* counts . . . turn to PACIFIC!

DESIGN FEATURES FOR MORE EFFICIENT, MORE ECONOMICAL OPERATION:

- Cam profiled ways insure smooth action, gas-tight door
- Air operated door
- Alloy capped car piers for flat working surface for retort
- Multiple zone control
- Heating elements on all side walls, door and car hearth
- Temperatures from 900°F. to 2200°F.
- Uses any protective atmosphere including hydrogen



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☐ Please send me all information available on a furnace for _____(type of work).

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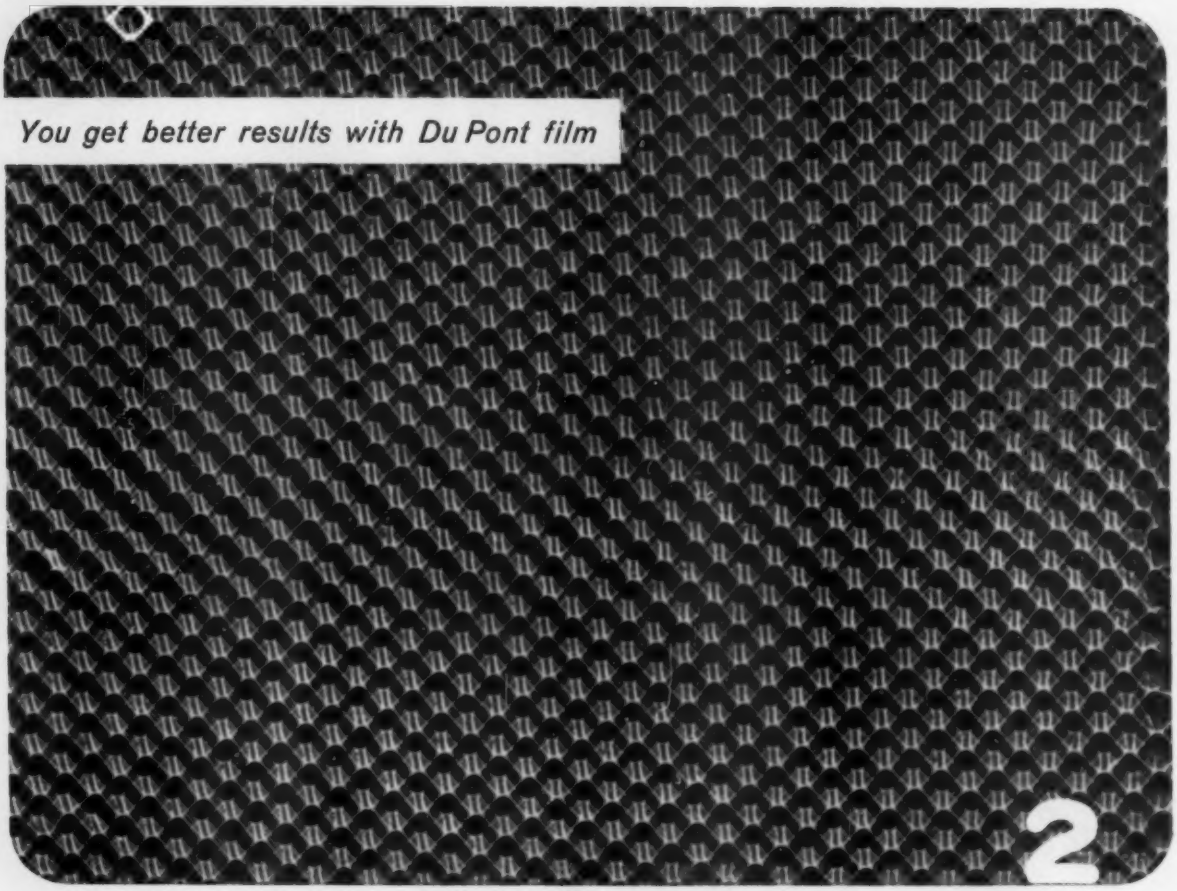

"For finest definition...510 x-ray film"

says Aeronca Manufacturing Corporation, Middletown, Ohio

Aeronca has found that Du Pont Type 510 X-ray Film has the very fine grain and extreme sensitivity necessary for x-ray inspection of difficult subjects like the honeycomb panel shown in the radiograph above.

Mr. Herbert J. Davis, Supervisor of Aeronca's Engineering Laboratory, tells why 510 film is standard for quality control on these panels:

"We make honeycomb panels for use in military aircraft and missiles—and they must meet rigid specifications. The inner lattice of compartments is sandwiched between two sheets of metal and all joints brazed. There must be an even amount of brazing metal on all joints, without voids that could cause structural failure.

"The minute burrs that cause these voids are from .005" to .008" in section," says Mr. Davis. "Du Pont 510 Film has the very fine grain needed to visualize these burrs. The wide latitude of this film shows us detail in materials having considerable variation in section thickness."

If you need x-ray films with this high sensitivity, combined with experienced technical service, call the nearest Du Pont Sales Office, or write Du Pont Photo Products Department, 2432-A Nemours Building, Wilmington 98, Delaware. In Canada: Du Pont Company of Canada (1956) Limited, Toronto.

DU PONT

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Better Things for Better Living . . . *through Chemistry*

OSTUCO WELDED TUBING

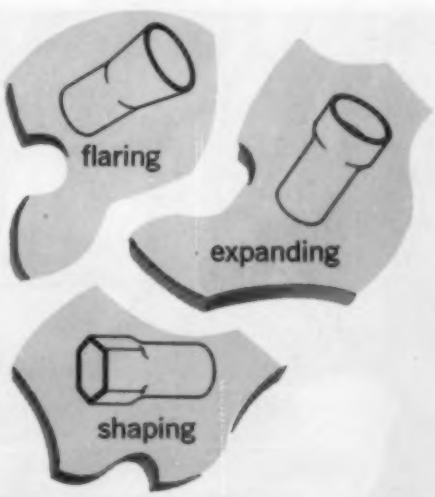
solves your fabrication puzzles

Product design dilemmas . . . or production problems? Solutions to these perplexing puzzles fall right into place *naturally—with Ostuco Welded Tubing.*

First, Ostuco Welded Tubing is one of the most versatile of all materials. It can be subjected to virtually every fabricating operation known.

Second, we can perform any one or more of these fabricating operations. That means you add us to your production line without investment in equipment, inventory or plant.

Third, when you deal with Ohio Seamless you're dealing with tubing *experts* . . . men who can recommend the *exact* Ostuco Welded Tubing to suit your product and processes. Just contact our nearest sales office, or the plant at *Shelby, Ohio—Birthplace of the Seamless Steel Tube Industry in America.* AA-7061



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1908 1958

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Why automotive manufacturers prefer N-A-X® FINEGRAIN STEEL for bumpers

WIDE RANGE OF SHAPES AND CONTOURS
The complexity of today's automotive bumpers demands a steel that provides maximum strength plus unlimited shape and contour possibilities.

FLAT POLISHES TO A HIGH LUSTER
The hardness and fine grain of N-A-X FINEGRAIN renders this steel capable of assuming a high degree of luster at minimum cost.

REDUCES POLISHING COSTS
Bumpers made of polished N-A-X FINEGRAIN suffer no surface disturbances due to coarse grain or strain caused by the drawing process. Preparation costs before plating are thereby reduced.

LESS OVERHANG WEIGHT
Generally, the most difficult bumpers can be made of N-A-X FINEGRAIN with a minimum of 25% increased yield strength over mild carbon steel. This makes possible greater resistance to indentation and substantially decreased overhang weight.

No wonder automotive manufacturers prefer dependable N-A-X FINEGRAIN for the difficult jobs.

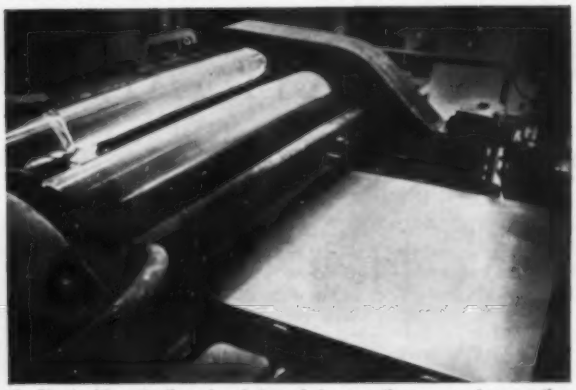
CHECK THESE IMPORTANT ADVANTAGES FOR YOUR JOB:
N-A-X HIGH-STRENGTH steels—both N-A-X HIGH-TENSILE and N-A-X FINEGRAIN—compared with carbon steel, up to 50% stronger • have high fatigue life with great toughness • are cold formed readily into difficult stampings • are stable against aging • have greater resistance to abrasion • are readily welded by any process • offer greater paint adhesion • polish to a high luster at minimum cost.

Although N-A-X FINEGRAIN'S resistance to normal atmospheric corrosion is twice that of carbon steel, N-A-X HIGH-TENSILE is recommended where resistance to extreme atmospheric corrosion is important.

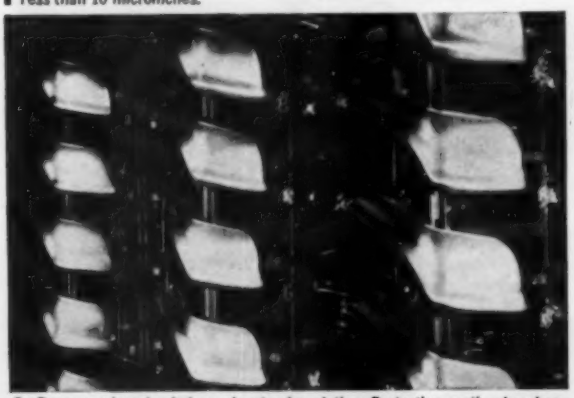
For whatever you make, from steel boats to steel bumpers, with N-A-X HIGH-STRENGTH steels you can design longer life, and/or less weight and economy into your products. Let us show you how.

3 Bumper wings, drawn double from N-A-X FINEGRAIN, emerge from press. After splitting and trimming, the protective draw coating is removed. Contoured bumper is then ready for plating without subsequent polishing.

1 Hot rolled N-A-X FINEGRAIN sheets come out of flat polish with a finish of less than 10 microinches.

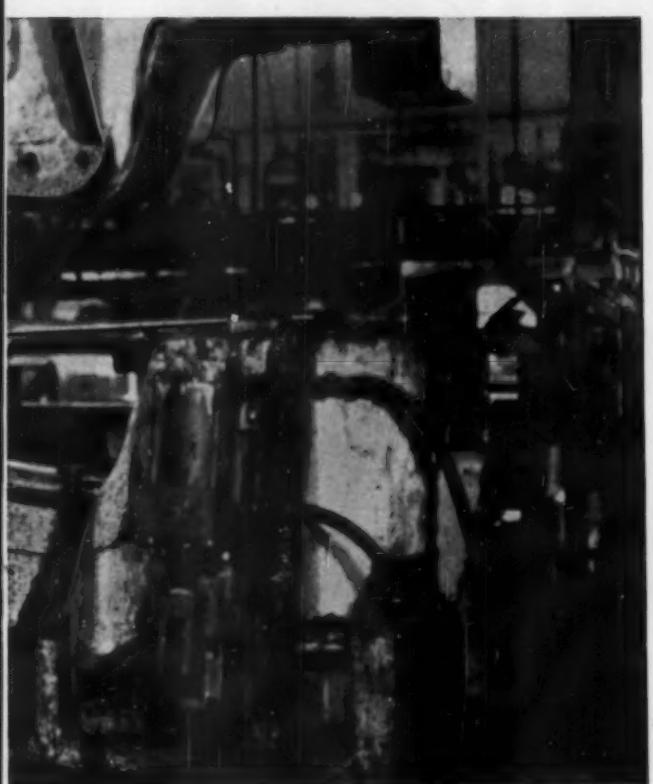


2 Sheet with protective phosphate and draw coatings comes from coating machine ready for the draw press.



4 Bumper wings loaded on elevator for plating. Protective coating has been removed. Note no surface disturbances occurred after drawing operation.

5 Final inspection after plating. No expensive hand-polishing was required from original flat polish to plating operation.



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Great Lakes Steel Corporation, Detroit 29, Michigan

☐ Please send me 12-page illustrated technical catalog on N-A-X HIGH-STRENGTH steels.

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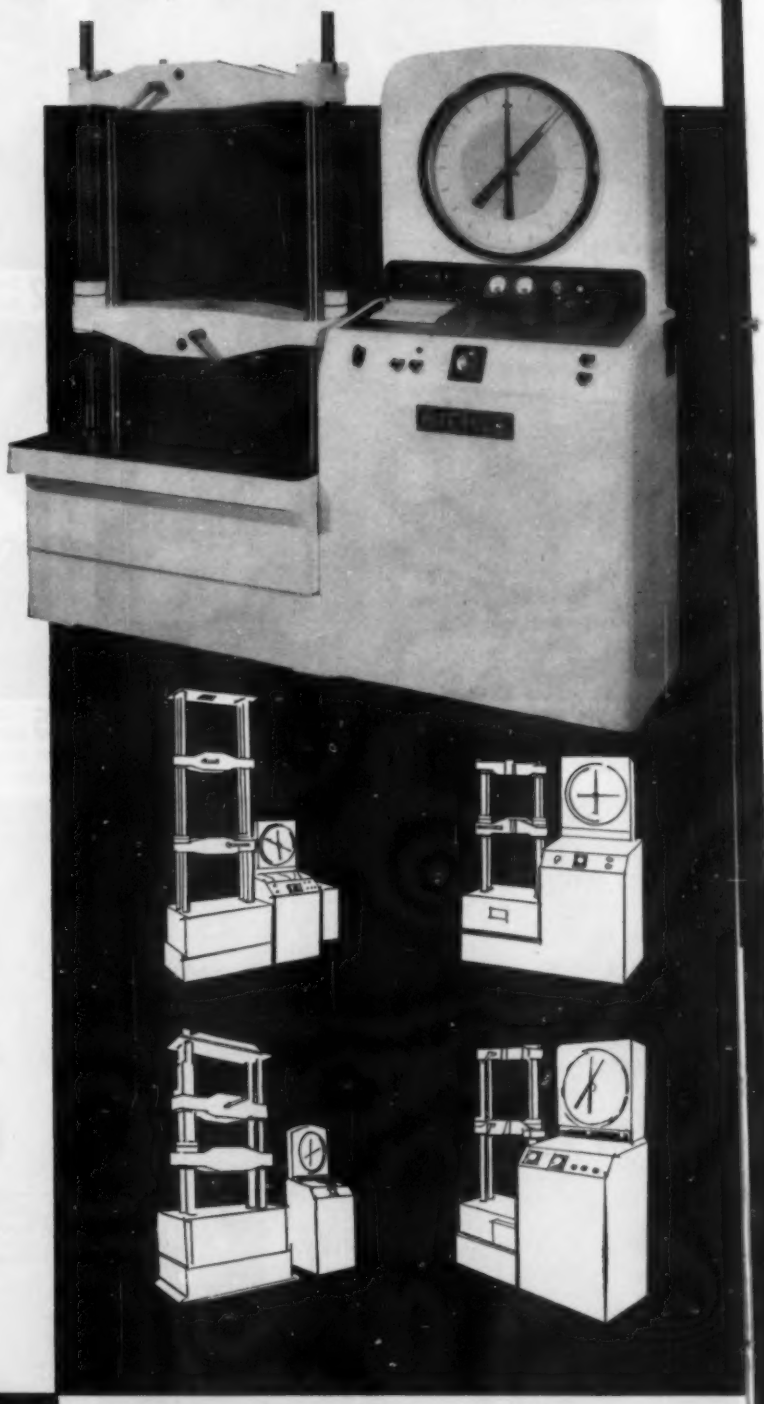
These universal testing machines

FACILITATE ALL MODERN RESEARCH AND CONTROL PRACTICES



Today's stringent testing requirements and demanding test schedules call for a universal testing machine with both the high sensitivity and rapid response of a Riehle. In addition, progress in modern practices of research and production control demand the broad flexibility that a Riehle provides.

For example, equipment and instruments now available bring programmed tests for both creep and relaxation and under vacuum furnace conditions into the scope of this machine's functions.

Hydraulic and screw power testing machines are available in capacities from 2,000 lbs. to 450,000 lbs. as standard. Riehle welcomes special application problems for testing equipment.

OTHER RIEHLE TESTING MACHINES: Creep and Stress-Rupture Testing Machines, Hydraulic Fatigue Testing Machines, Construction Materials, Impact, Brinell, Torsion, Horizontal Chain, Rope and Cable Testers, Portable Hardness Testers for Rockwell Readings, Etc.

Riehle TESTING MACHINES

A DIVISION OF

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ATTENTION MR. _____

APPLICATION and EQUIPMENT new products

Furnace

Waltz Furnace Co. has announced a car bottom furnace which needs neither pits nor rails below the floor level. The car is motor driven by a rack and a pinion. There are additional wheels inside the furnace to pick up the car as it runs in. The furnace shown is 3 ft. wide by 3 ft. high by 6 ft. long. The heating elements are mounted on both side walls, the back wall, the door and the car. They are connected to a 440 v., 3 phase, 60 cycle contactor and draw 100 kw. The temperature panel is shown next to the contactor panel. In the roof

of the furnace is a motor driven fan to provide circulation at lower temperatures. This fan is designed for 1800° F. operation and has a water cooled shaft.

For further information circle No. 215 on literature request card, page 48-B.

X-Ray Film

The Gevaert Co. of America has announced a new X-ray film designed for recheck and laboratory research work. It is made for inspection of thin or medium-thick sections of light metal at low and medium kilovoltages. It has high radiographic sensitivity and fine grain for maximum detail.

For further information circle No. 216 on literature request card, page 48-B.

Magnetic Inspection

A portable magnetic inspection device which detects surface and subsurface defects in ferro-magnetic material has been announced by Ferro Machine & Tool Corp. The Ferroflux unit weighs 23 lb., and consists of a U-shaped 110-volt electro magnet which operates at 0.175 kva. The magnetic field which is set up is strong enough to lift more than the unit's weight of

23 lb., so it will cling to the surface it is checking, allowing the operator's hands to be kept free to handle the detection fluid. The unit is placed on the part to be explored, so that both poles are in contact with the part. The current is turned on and the space immediately surrounding the pole assembly is painted with a solution holding minute particles of iron in suspension. These iron particles will concentrate wherever there is a surface or subsurface break in the magnetic field. Such defects as cracks, laps, discontinuities, voids, slag inclusions, seams, grinding checks, and hard spots are disclosed, whether such defects are on the surface, or beneath the surface.

For further information circle No. 217 on literature request card, page 48-B.

High-Temperature Furnace

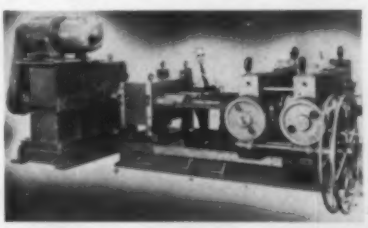
The Zirconium Corp. of America has announced a laboratory-size furnace for use at temperatures up to

4600° F. in oxidizing atmospheres. It is 21 in. high by 18 in. in diameter with a 6 in. in diameter by 6 to 8 in. deep firing chamber. It can be used to sinter ceramic materials and can be adapted to crucible melting with tilt pouring and high-temperature material testing. The fuel used is oxygen-acetylene. Oxygen or compressed air can also be used with hydrogen, natural gas or propane, if desired.

For further information circle No. 218 on literature request card, page 48-B.

Rolling Mill

The Fenn Mfg. Co. has announced a convertible rolling mill that can be used as a vertical mill for rolling powdered metals or converts to a standard horizontal mill for rolling



strip. The mill shown is a two-high/four-high combination mill with 12 in. rolls, 40 hp. variable speed a.c. drive.

For further information circle No. 219 on literature request card, page 48-B.

Steel Shot

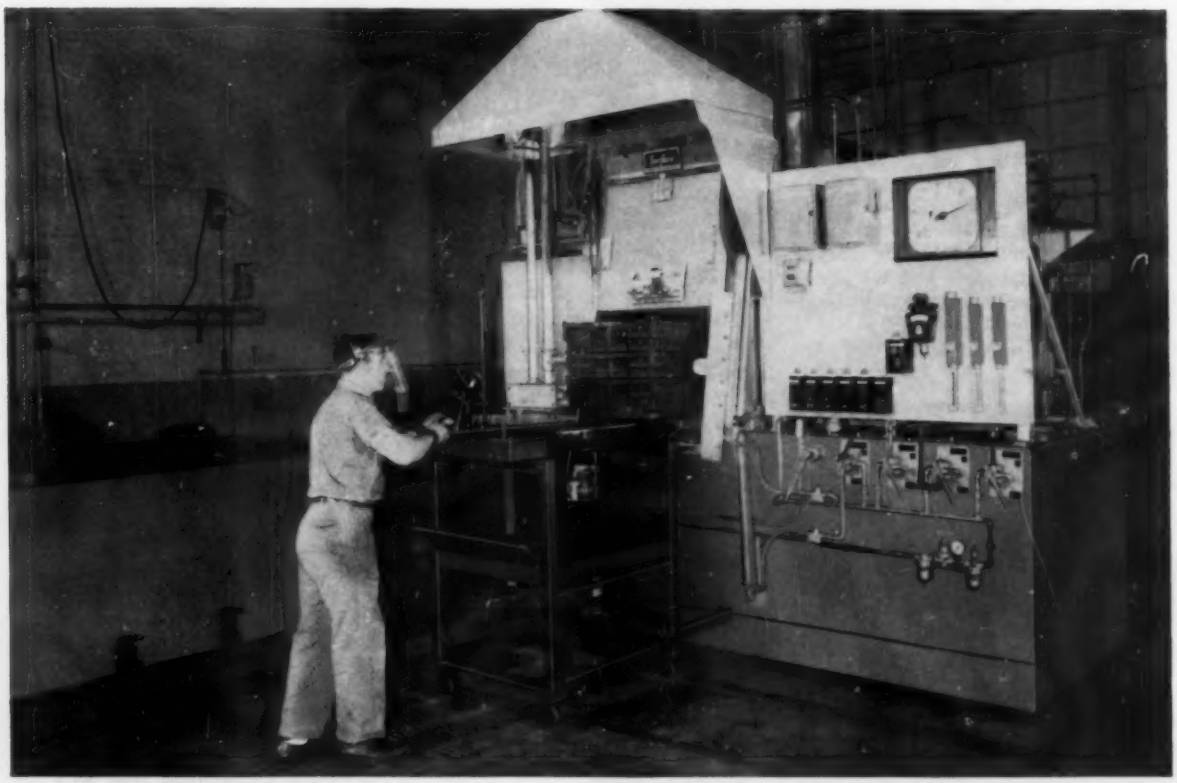
Pangborn Corp. has announced new steel shot for blast cleaning. The abrasive is vacuum cast. It is then heat treated in a continuous atmosphere furnace, quenched and drawn. Rotoblast steel shot is available in all standard S.A.E. sizes.

For further information circle No. 220 on literature request card, page 48-B.

Metal Marking

Pannier Corp. has announced a new portable pneumatic marker for hot and cold metal marking. The unit's over-all length is 2 ft.; it weighs 14 to 16 lb., including type head and type. Air pressure as low as 50 lb. will

Allcase® furnace clips cost ½ on manicuring implements



One man and one furnace now match the former production of two men and two furnaces in this plant. Added to this gain are two others: greater versatility in processing, and finished work of uniformly high quality. The latter is especially important to this manufacturer of manicuring implements, because he offers a lifetime guarantee on many of his products.

The "hero" of this story is the Surface Allcase® furnace, which is used for hardening, carbonitriding, carburizing, and annealing. Controlled atmosphere is supplied by a Surface MRX® gas generator. Work handling and atmosphere control can be completely automatic, if you wish. Why don't you find out about this profitable furnace now?

Write for Bulletins SC-163 and SC-174.

Surface Combustion Corporation, 2377 Dorr St., Toledo 1, Ohio. In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ontario.

Surface

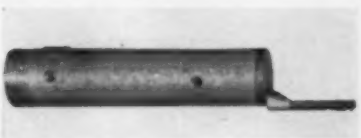
wherever heat is used in industry

operate this hammer which has its own surge chamber so that distance from main air supply does not affect the impression uniformity. The marker is available in three models.

For further information circle No. 221 on literature request card, page 48-B.

Surface Roughness

Micrometrical Mfg. Co. has announced a new Profilometer LK Tracer which makes it possible to take surface roughness measurements



on ⅛ in. i.d.'s to a depth of 11/16 in. It will measure i.d., o.d., flats, tapers, narrow splines, and gear teeth by means of three interchangeable skid-mounts.

For further information circle No. 222 on literature request card, page 48-B.

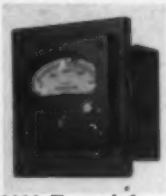
Solar Furnace

A new and automatic solar furnace has been announced by Thermal Dynamic Products. It has a fully automatic electronic solar tracking system to maintain precise alignment of the parabolic lens with the sun, as well as motor driven remote controls for sample positioning and temperature adjustment. The temperature of the solar furnace can be adjusted to any desired operating level, up to 7000° F. Heat is instantly available. When the furnace is turned on, maximum temperatures are attained immediately. The solar furnace eliminates all contaminating influences such as electrical and magnetic fields, and all foreign gases and chemicals. Inasmuch as no special crucible is required for the specimen being analyzed, there are no impurities to contaminate the molten residue. Atmospheres can be controlled through use of a hemispherical bell jar test chamber. The furnace is mobile.

For further information circle No. 223 on literature request card, page 48-B.

Temperature Controller

A new pyrometer-type temperature controller has been announced by Illinois Testing Laboratories. It requires ⅛ sq. ft. of panel space and is available in three case styles. Only one electron tube is used to operate the relay and respond to the temperature indicator. The instrument is available in ten ranges, 0 to 400° F., to 0 to 3000° F., and four thermocouple alloys, chromel constantan, iron constantan, chromel alumel and platinum platinum rhodium.



For further information circle No. 224 on literature request card, page 48-B.

X-Ray Film Processing

Picker X-Ray Corp. has announced Nikor film processing equipment which will develop long strips of 70

mm. X-ray film used for radiographing circumferential welds in large pressure vessels. It will handle any length of film up to 100 ft. The Nikor setup includes: a reel to hold the film, a jig to load the film onto the reel, and three solution tanks.

For further information circle No. 225 on literature request card, page 48-B.

Optical Gage

Bausch & Lomb Optical Co. has announced an all-purpose inspection and quality control optical gage which measures depth, thickness, height, and diameter. Measuring range is continuous from 0 to 3 in., with no

. . . a machine with "A GOOD RECORD as a REVENUE PRODUCER"

A typical case of using a Niagara Aero Heat Exchanger to provide cooling for production equipment shows amortization of this machine in 16 months and $90 per day revenue thereafter.

Industrial engineers with careful cost, upkeep and revenue records on all machines, credit Niagara Aero Heat Exchangers with important gains over other methods.

They use these machines to provide cooling for production equipment, welders, extruders, drawing dies, furnaces, quench baths, plating, chemical and electronic process...all millwater system uses.

They get positive control of critical process temperatures with improved product quality, rejection losses prevented. Heat is removed at the rate of in-put.

A closed system, dirt free prevents all troubles from bad water; transferring heat to the atmosphere by the evaporation of a very small amount of water solves all problems of water supply or disposal.

Write for Bulletins 120, 135

NIAGARA BLOWER COMPANY

Dept. MP-8, 405 Lexington Ave., New York 17, N.Y.

Niagara District Engineers in Principal Cities of U. S. and Canada

PHOTO COURTESY OF METLAB COMPANY

12-ft catapult rails vertically quenched, perfectly hardened in SUN QUENCHING OIL LIGHT

Steam-catapult rails for aircraft carriers *have* to be straight and perfectly hardened.

So Metlab Company, Philadelphia, uses an inverted-pit vertical quench from atmosphere into Sun Quenching Oil Light to assure maximum resistance to deformation.

Sun Quenching Oil Light has been used exclusively for over eight years throughout this major heat-treating plant, because "it is unsurpassed by any other oil ever used . . . regardless of price."

The consistent quality and long life of Sun Quenching Oil Light are cost-cutting characteristics that could well benefit *your* quenching operations.

Ask your Sun representative *why* Sun Quenching Oil Light meets such a wide variety of quench needs. Or write, for free technical data on all Sun Quenching Oils, to Dept. MP-8.

Industrial Products Department

SUN OIL COMPANY, Phila. 3, Pa.

SUNOCO

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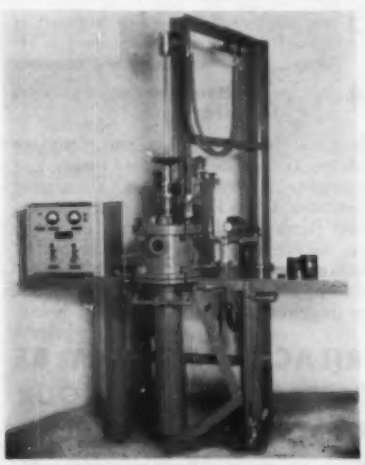
masters or set gages needed. Measurements are read directly on an illuminated, magnified scale graduated in intervals of 0.0001 in., with an accuracy of 0.000025 in. Most parts are laid on the anvil for measurements to be made. A turn of the control knob lowers the spindle until it touches the part. The spindle stops on contact and the measurement is read.

For further information circle No. 226 on literature request card, page 48-B.

Furnace

A new furnace developed for eliminating ingot losses due to the cropping of arc-melted ingots of nuclear material has been announced by Vacuum Specialties Co. The top of the ingot is remelted by a revolving offset electrode, guided by hand. The



shrinkage cavity can be filled in and the top of the ingot smoothed off. The operation can be carried on under full vacuum or inert atmosphere.

For further information circle No. 227 on literature request card, page 48-B.

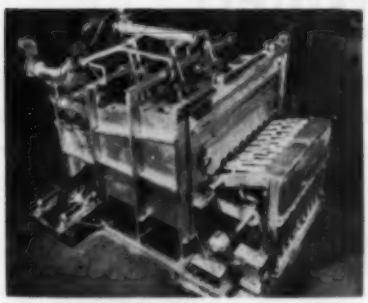
Tube Mill

A new process for producing continuous seam-welded ferrous and nonferrous tubing has been announced by Induction Heating Corp. and American Roller Die Corp. The equipment combines a high-frequency induction generator and a tube-forming mill. Frequencies up to 3000 k.c. are employed.

For further information circle No. 228 on literature request card, page 48-B.

Forge Heating

Cone burners for a pusher-type furnace, built by J. A. Kozma Co., designed to heat 2500 lb. of steel forgings per hour to 2250° F. with 4 million Btu. per hr. input, based on 20% efficiency, have been announced by Hauck Mfg. Co. These burners, using low-pressure gas and air, down-fire



through the roof of the furnace. Because of the short flame length developed by these burners and low forward velocity of combustion gases, the burner cones can be placed close to the forgings without danger of flame impingement. This results in intense heat radiation and rapid, uniform heat absorption.

For further information circle No. 229 on literature request card, page 48-B.

Testing Machine

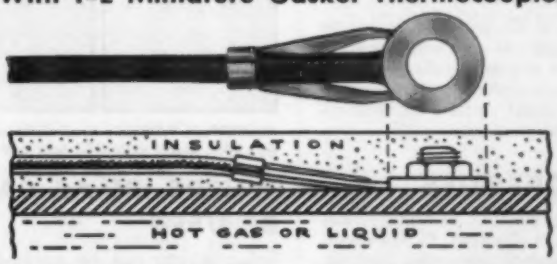
Marquardt Aircraft Co. has announced a new mechanical-properties testing machine designed to automatically test metals at temperatures to 3000° F. The machine has a capacity to 50,000 lb. in both tension and compression so that full-size A.S.T.M. samples can be tested. Specimens can be heated electrically at controlled rates from 0 to 200° F. per second, to temperatures to 3000° F. On a single specimen, the machine will automatically test for any combination of load, temperature and time, i.e. tension, and compression; creep and stress-rupture; low frequency fatigue; and thermal fatigue.

For further information circle No. 230 on literature request card, page 48-B.

Dew Point Controller

Ipsen Industries has announced a new dual Dewtronik, consisting of two complete atmosphere sampling, analyzing and controlling units mounted

Fast, Accurate
Skin Temperature Measurement
With T-E Miniature Gasket Thermocouples



Easily installed, T-E's fast responding, sensitive, gasket thermocouples have many applications. They provide accurate, dependable skin temperature measurement for chemical, food processing, metal working, atomic energy and many other industries.

In a typical installation, a gasket thermocouple is secured with a nut onto a bolt or stud located in the area of desired temperature measurement. This assembly may then be covered with thermal insulation. Another typical use is beneath engine spark plugs.

Choice of three temperature ranges covers minus 300°F. to plus 1200°F. Calibrations include either Copper-Constantan or Iron-Constantan. Standard washers are available for studs and bolts from 1/8" to 1" in diameter. A wide selection of terminals or quick-coupling plug and jack connectors to suit your needs.

Write for Bulletin 1-H.

Thermo Electric Co. Inc.
SADDLE BROOK, NEW JERSEY
In Canada—THERMO ELECTRIC (Canada) Ltd., Brampton, Ont.

Introducing Allied's

IRILAC™ #1000

New Clear Protective Coating for All Metals . . . as safe and easy to handle as Water!

New method of protection incorporates corrosion inhibitors in a water-soluble polymer base. Dries to an extremely thin, tough, durable coating—clear in color. Does not chemically affect base metal or any post-treatments. Used as a protective treatment alone or to enhance value of post-treatments.

Allied's new Irilac #1000 is a concentrated solution of a water-soluble polymer with built-in complex corrosion inhibiting materials. It was developed to answer the needs of the metalworking industry for a non-conversion process that will provide corrosion resistance and resistance to fingerprinting and abrasion on base metals and electrochemically or chemically finished surfaces—without changing the appearance of the metallic surface.

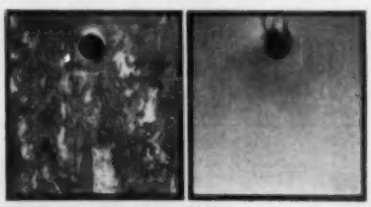
There are no hazards involved—Irilac is non-fuming, non-toxic, and requires no special fire prevention measures.

THE PROCESS

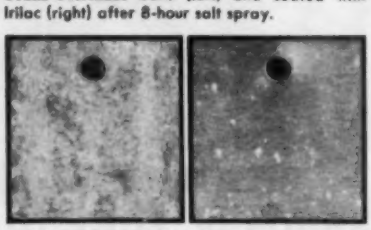
Irilac #1000 is diluted with water to provide a simple one-pass working solution. It is then applied by dip, brush or spray and forms a coating that quickly *bonds* to the metal surface without reacting with the surface.

THE PROPERTIES

The resulting coating is clear, transparent, thin yet durable. It has excellent water-resistant properties, and can be rubbed, handled and subjected to rough treatment. The surface to which Irilac has been applied is not altered—in fact, the transparent coating brings full tone to colored surfaces and clarity to iridescent surfaces. The water-thin physical characteristic of the solution means that the coating provides protection in recessed areas that are difficult, if not impossible, to protect with other methods.



STEEL PANELS: bare (left) and coated with Irilac (right) after 8-hour salt spray.



ALUMINUM PANELS: bare (left) and coated with Irilac (right) after 168-hour salt spray.

WHERE IRILAC CAN BE USED

Irilac #1000 can be applied to *any* metal—wet or dry—treated or untreated. All metals can be processed in *one* operation in the same solution. It can be applied in conjunction with any process—over Iridite, anodized, phosphated surfaces, black oxide, etc. Surfaces treated with Irilac provide a good base for paint.

APPLICATION ADVANTAGES

No other process or material available for the protection of metals offers all the application advantages found in new Irilac #1000:

1. It can be applied to *any* clean metal simply by dip, brush or spray. No special equipment is required.
2. Saves time—just apply and dry—no reaction time required.
3. No hazards involved—no exhaust or special fire protection equipment is required. Irilac is non-fuming and non-toxic.
4. Saves space. Presents no disposal problem. Low in first and final costs.

Because of its versatility and complete safety, Irilac has unlimited uses. For example, it will protect aluminum furniture, brass hardware and fixtures, steel parts of all types, zinc castings, etc. In fact, any base metal or plated surface, or those treated with electrolytic or chemical post-treatments, can be improved or enhanced with Irilac.

IRILAC #1000 MAY BE THE ANSWER TO YOUR PROTECTION PROBLEM

Our development staff will be glad to work with you to determine the significant benefits Irilac can offer you. Simply send us some parts and let us show you what Irilac can do. No obligation, of course.

Allied Research Products, Inc.

4004-06 EAST MONUMENT STREET
BALTIMORE 5, MARYLAND

Manufacturers of IRIDITE®, IRILAC™, ARP® Brighteners and Plating Chemicals
West Coast Licensee: L. H. Butcher Co.

in one cabinet, with one two-record strip chart, indicating and recording controller. The dual instrument will control endothermic-type special gas

atmospheres as sampled from two generators, one generator and a related or separate furnace, two furnaces, or two zones in the same furnace.

For further information circle No. 231 on literature request card, page 48-B.

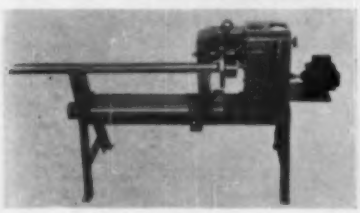
Furnace Retorts

The Stanwood Corp. has announced a new line of furnace retorts, furnished in Cor-Wal construction and available in all standard sizes. This construction consists of heat resistant, corrugated rolled metal sides with a one piece cast, reinforced top seal. The various parts are welded together. The increased surface area provided by the corrugating process results in efficient heat transfer.

For further information circle No. 232 on literature request card, page 48-B.

Hardness Tester

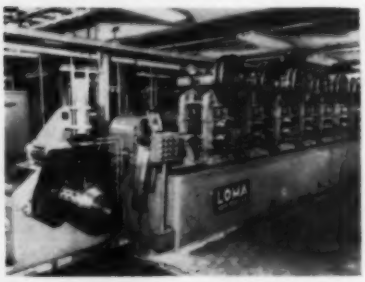
A Brinell testing machine for production testing of flange members on long shafts, such as axle assemblies, has been announced by Detroit Testing Machine Co. Hydraulically powered, it carries two dials, one showing load applied and the other a direct reading dial for comparative checking, using hand-set high and low limit indicating needles. The anvil and testing ball may be interchanged to allow test impressions to be made on either side of the part.



For further information circle No. 233 on literature request card, page 48-B.

Strip Mill

A new high-speed cold reduction mill for continuous rolling of thin strip has been announced by Loma Machine Mfg. Co. The new machine features a layout of eight individual 6 in. diameter by 8 in. face two-high mill stands mounted with their drives on one common base. Each set of rolls is driven by a 40 hp. variable speed d.c. motor through a combination gear reducer and pinion stand and a pair of universal joint spindles. The rolls are made of forged alloy steel and



are hardened to 100 Shore Scleroscope. The machine normally is fed with annealed re-roll stock ranging from 0.072 to 0.093 in. gage.

For further information circle No. 234 on literature request card, page 48-B.

Cleaner

A new reverse current cleaner has been announced by Oakite Products, Inc. Oakite Composition No. 190 will clean heavily smutted steel. It also removes fingerprints, light surface rust and oxides resulting from spot or seam welding. The material is used at concentrations from 8 to 16 oz. per gal. of water, at temperatures ranging from 180 to 200° F., with reverse current, from 40 to 100 amp. per sq. ft. It may be used with or without a precleaner. It rinses in hot or cold water.

For further information circle No. 235 on literature request card, page 48-B.

Tube Tester

Steel City Testing Machines has announced an automatic air machine which tests approximately 2100 cooler tubes an hour with rejection of those with leaks. The pulley-operated hopper feeds tubes into slots of a 16-station drum. When the drum revolves to a filling position, 50 lb. of air pressure is applied into the tube. Satisfactory

SAVE FUEL,
REDUCE COSTS
ON YOUR FORGING
OPERATIONS
WITH . . .

Radiant

ROOF PANELS

READY-TO-INSTALL
PRE-PIPED UNITS

- Provide faster, more uniform heat distribution
- Boost furnace efficiency as much as 100%
- Eliminate flame impingement
- Cut scaling to a minimum
- Increase die life
- Save on fuel
- Give greater operator comfort

Whether you're building a new forging furnace or rebuilding an old one, KOZMA RADIANT ROOF PANELS will cut your construction and operating costs!

Panels consist of radiant cup-type burners mounted in a one-piece refractory tile, ready for quick, easy installation.

High speed combustion permits installation of panel closer to work. Intense heat radiation, plus faster, more uniform heat absorption can greatly reduce required heating time per piece.

Kozma Radiant Roof Panels are available in a wide range of sizes to meet your specific requirements.

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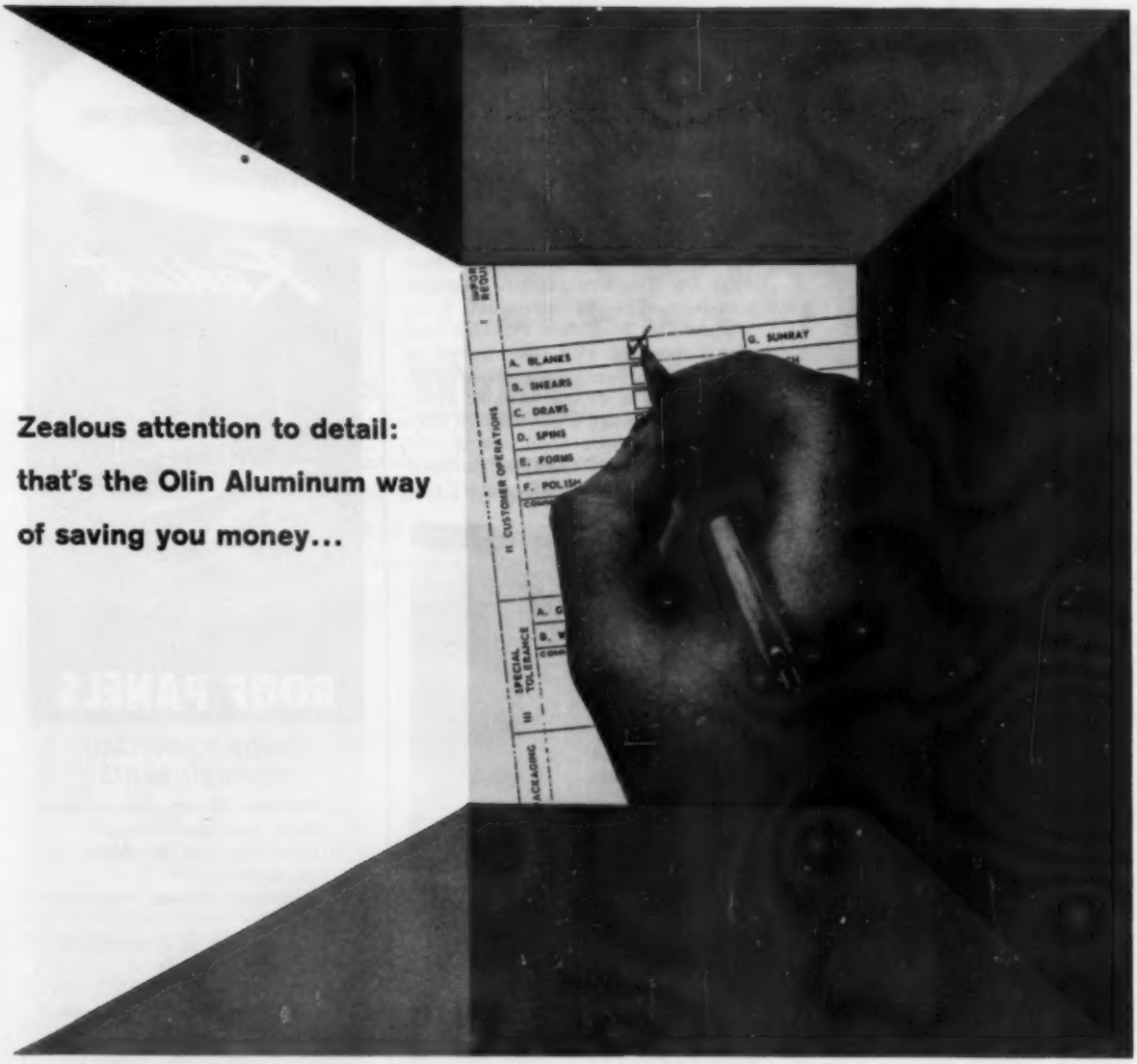
J. A. KOZMA Company
2471 WYOMING
DEARBORN MICHIGAN

"Industrial Processing Furnaces Since 1928"

Zealous attention to detail: that's the Olin Aluminum way of saving you money...



Product that's exactly what you want . . . inspected to your individual standards . . . packed and shipped in the bulks and sizes you can best handle. This kind of personalized Olin Aluminum service, and constant watchfulness, can save you time and trouble—and that means money.

To achieve this, we cram our Customer Requirement Record with more detailed facts about your operations, needs, likes and dislikes than anyone else, we believe. But that's where we see our biggest future: in offering you personalized individual service that fits you like a glove.

If you'd like this kind of special attention and service, call the nearest of our 29 offices or write: Aluminum Division, Olin Mathieson Chemical Corporation, 400 Park Avenue, New York 22, N. Y.

Symbol of New Standards of Quality and Service in the Aluminum Industry

OLIN MATHIESON CHEMICAL CORPORATION
OLIN ALUMINUM

® AND "OLIN ALUMINUM" ARE TRADEMARKS

parts complete a full cycle and are ejected at the front of the machine. Leaking tubes are automatically

ejected at the rear of the machine. The 16-station drum has a 12 in. diameter, is turned by a speed reducer and revolves at 2.2 rpm.

For further information circle No. 236 on literature request card, page 48-B.

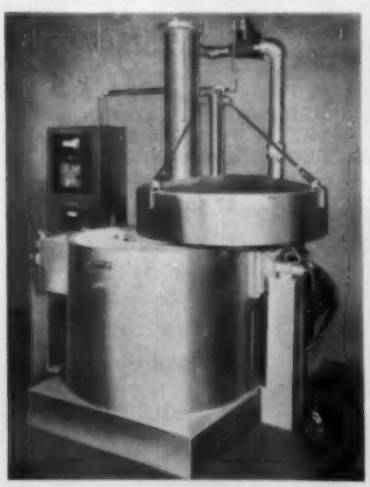
Hardness Tester

The King Tester Corp. has announced a new model Brinell tester for hardness tests on interior walls of cylinders or cylindrical openings. This portable tester uses a 5 or 10 mm. carbide ball with loads ranging from 500 to 1500 kg. The tester can be furnished for openings with a minimum diameter of 6 in. and can make tests at a depth of 10 in. or more. For large size pipe, extensions can be furnished to hold test head in position and tests can be made at any point on the inside walls.

For further information circle No. 237 on literature request card, page 48-B.

Furnace

A new gas-fired furnace which will fire continuously up to 3300° F., using fuel gas with a rating of 1000 Btu. or better, has been announced by Harrop Electric Furnace Div. The tangentially fired cylindrical furnace cycles automatically, reaching 3300° F. and then cooling, ready for unloading. It is available in pedestal diameter of 8,

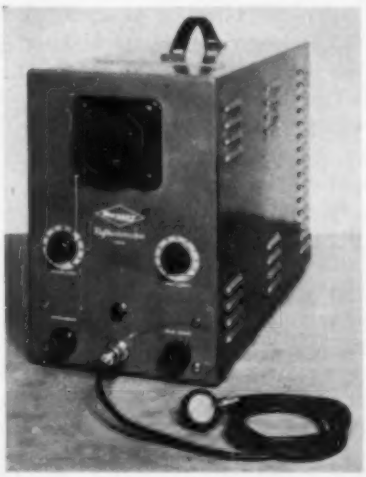


12, 18, or 36 in. and setting height of 12, 16, 20, or 40 in. The 8 and 12 in. sizes are usually built with an arch that rises and swings aside (as pictured). The 18 and 36 in. sizes are usually elevator type, with a pedestal that lowers and then moves from beneath the furnace.

For further information circle No. 238 on literature request card, page 48-B.

Inspection

A new portable Reflectoscope for ultrasonic inspection has been announced by Sperry Products. It oper-

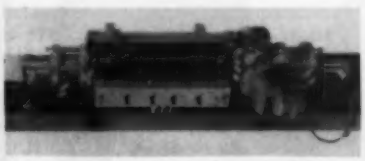


ates at 2.25 megacycles, weighs 35 lb. and measures approximately 9 in. wide, 19 in. deep and 14 in. high.

For further information circle No. 239 on literature request card, page 48-B.

Vacuum Furnace

Riehle Testing Machines Div. has announced a high-temperature vacuum furnace for use with its creep testing and universal testing machines. It is complete with integral record-

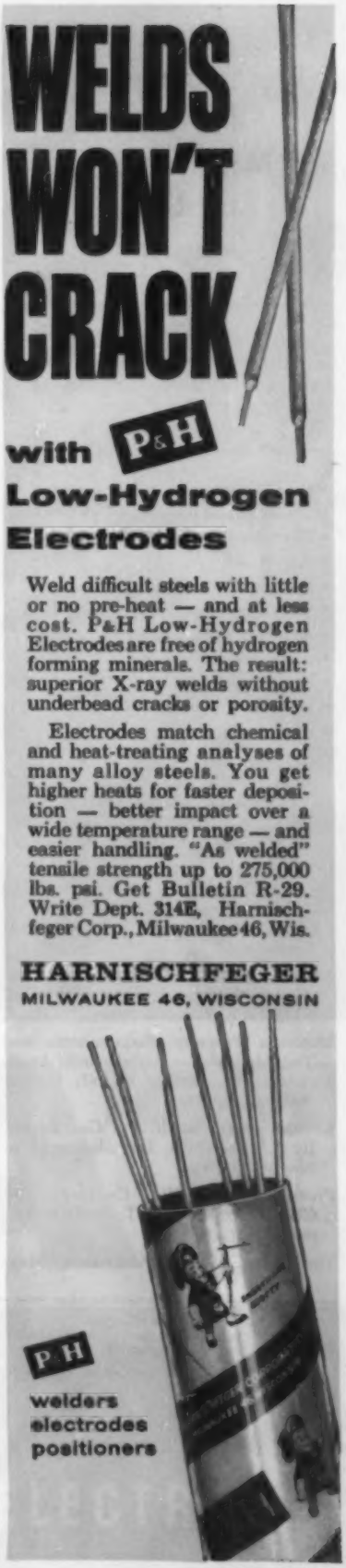


ing-type extensometer. Two models are available, operating at temperatures of 2000 and 3000° F., respectively. Vacuums of 1 x 10^{-5} mm. Hg can be effected. Specimen elongations up to 0.2 in. and up to ½ in. can be accommodated with currently available extensometers.

For further information circle No. 240 on literature request card, page 48-B.

Shot Peening

Metal Improvement Equipment Co. has announced a machine which automatically shot peens any crankshaft


WELDS WON'T CRACK
with P&H
Low-Hydrogen Electrodes
Weld difficult steels with little or no pre-heat — and at less cost. P&H Low-Hydrogen Electrodes are free of hydrogen forming minerals. The result: superior X-ray welds without underbead cracks or porosity.
Electrodes match chemical and heat-treating analyses of many alloy steels. You get higher heats for faster deposition — better impact over a wide temperature range — and easier handling. "As welded" tensile strength up to 275,000 lbs. psi. Get Bulletin R-29. Write Dept. 314E, Harnischfeger Corp., Milwaukee 46, Wis.
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P H
welders
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positioners

the Urgent Challenge for the Metallurgist and the Designer

Metals for Supersonic Aircraft and Missiles

New ASM Book based on the 1957 Albuquerque Conference on Heat Tolerant Metals for Aerodynamic Applications sponsored by the American Society for Metals and the University of New Mexico

This is a book for the *designer* and the *metallurgist* who must have an increasingly effective partnership to achieve urgent aircraft and missile goals. It is a book for specialists in—

- **aerodynamics**
- **ceramics and cermets**
- **electronics**
- **heat flow**
- **high temperature properties**
- **lubrication**
- **material procurement**
- **mechanical structures**
- **thermodynamics**
- **protective metallic coatings**
- **vibrations**

This important new book is the most complete collection of scientific and engineering information on what happens to metals in air vehicles and missiles during high-speed flight.

Dealing primarily with the thermal barrier, *the thermal thicket*, this book emphasizes the need for study of environments formerly unknown or of only theoretical interest, and of their effects on materials of construction. It emphasizes that rapid advances in development of vehicles and missiles has made it urgently necessary to learn to cope with these environments.

In 12 chapters and in 5 appendices (with a comprehensive subject index), 22 authors deal with the metals problems that will determine the rate at which these new vehicles and missiles can be developed, that affect vitally the relative position of the United States in all aspects of missile and aircraft development.

This complete documentation of the problems facing metallurgy and design, fabrication and testing, this study of progress to date, should be in your library for study and reference use. It is a new, up-to-the-minute, authoritative book—order now.

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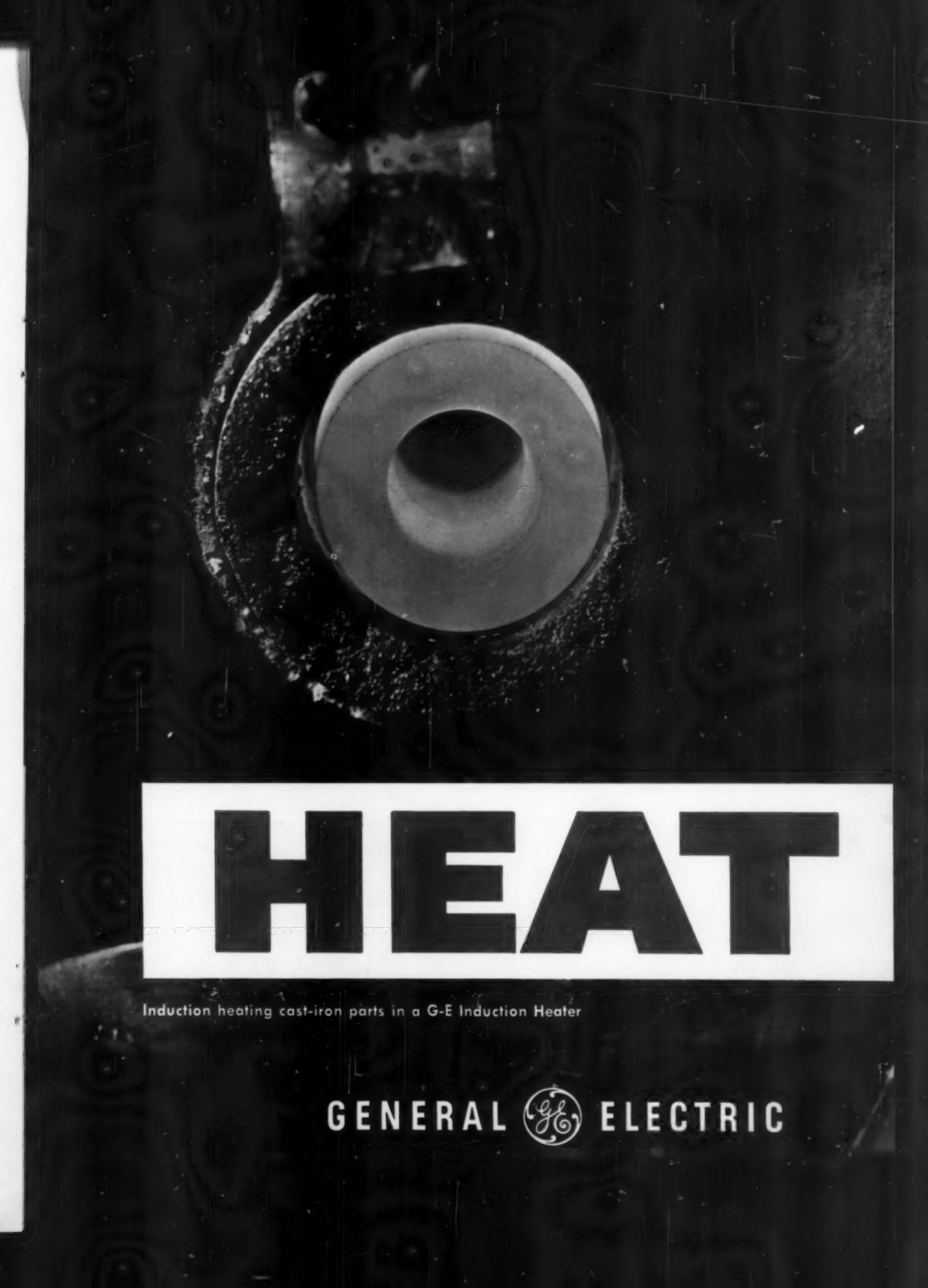
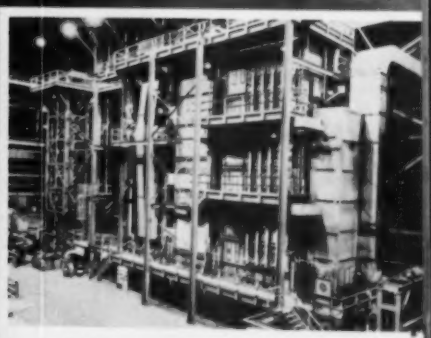
Watch for the early publication of the companion volume "Short Time High-Temperature Testing."



Induction heating cast-iron parts in a G-E Induction Heater

GENERAL ELECTRIC

HEAT



1. GAS/ELECTRIC tower furnace uses economical coke-oven gas.

. . . ENGINEERED BY GENERAL ELECTRIC ASSURES YOU LOWEST-COST HEAT SOURCE

A complete line of electric and gas-fired furnaces and induction heaters enables General Electric's qualified Heating Specialists to give you an unbiased solution to your heat treating problems.

Because General Electric supplies all types of Industrial Heating equipment including gas-fired and electric furnaces, induction heating units, and protective atmosphere producers and control, they can tailor a heat treating system for you which best meets your requirements. You get low first cost and low operating costs which will help pay for your system in two or three years and make substantial contributions to profit when the equipment is paid for.

Here are four examples of results achieved through heat systems engineered by General Electric (pictured below):

1. **EXTRA ECONOMY** is achieved by using coke-oven gas, a by-product of other manufacturing processes, in the gas-fired heat-up section of this new General Electric tin-plate annealing furnace. Electric heat is used to achieve close control of the holding and cooling sections.

2. **ADDING SUPPLEMENTARY BATCH FURNACE** capacity to handle special loads of copper wire at lower cost, this manufacturer found that gas was now his best buy, so he chose a General Electric gas-fired cylindrical bell furnace and endothermic gas atmosphere producer.

3. **REPLACING OIL-FIRED BATCH FURNACES** with two continuous G-E electric roller hearth furnaces, a Midwest foundry cut its cycle from 4 days to 48 hours, cut man hours by 40%. They report a 35% return on investment and have recently added a third General Electric furnace of the same type.

4. **SCRAP LOSSES WERE CUT FROM 35% TO 2%** with a G-E electronic induction heater used for brazing electric-switch housing and jet engine components. Resultant savings in manpower, materials and machine time have helped pay for the General Electric installation. Higher quality products are produced.

YOU CAN ACHIEVE RESULTS LIKE THESE with a heat modernization system engineered by General Electric to fit your needs. If you suspect that obsolete heat processing equipments are robbing you of profits, call your G-E Apparatus Sales Office. A qualified Heating Specialist will be glad to discuss your opportunities for potential savings and profits. Why not call today? Section 721-13, General Electric Company, Schenectady 5, New York.

2. RATE COMPARISONS showed gas furnace to be best buy.

3. ELECTRIC FURNACES cut cycle from 4 days to 48 hours, cut manhours 40%.

4. INDUCTION HEATER cut scrap losses from 35% to 2%.

GENERAL ELECTRIC

ALL OF THIS LITERATURE IS AVAILABLE FROM GENERAL ELECTRIC

- ☐ Furnace and Induction Brazing, GEA-5889
- ☐ How and where to use Electric-furnace Brazing, GEA-3193
- ☐ How to Braze Stainless Steel, GER-1331
- ☐ Heat Treating Aluminum, GEA-5912
- ☐ Annealing of Malleable Iron, GEA-5797
- ☐ How to Get the Best Results from Sintering Furnaces, GER-978
- ☐ Temperature Control of Heat Treating Furnaces, GER-1206
- ☐ Protective Atmospheres for use with Industrial Furnaces, GEA-5907
- ☐ New General Electric Induction Heaters, GEA-6388
- ☐ Catalog of General Electric Heaters and Devices, GEC-1005

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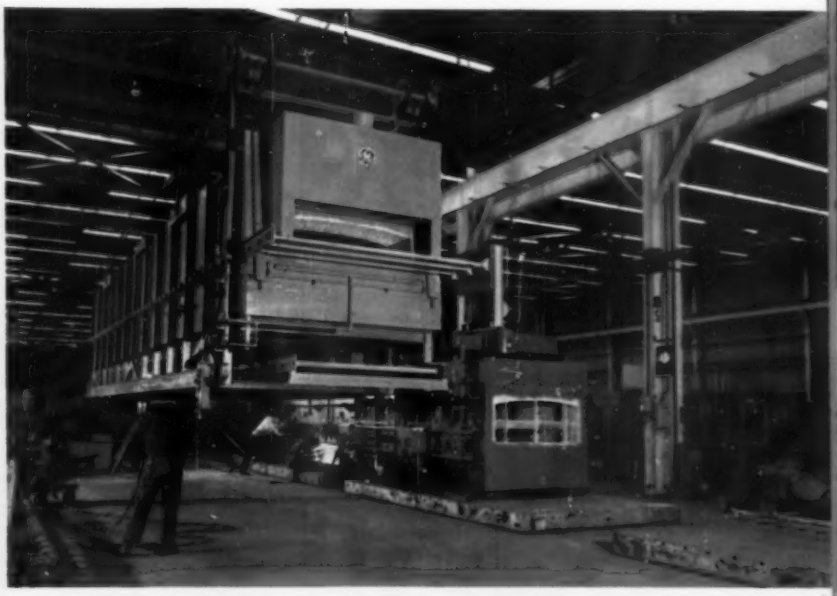
G-E MATERIALS HANDLING SYSTEMS SPEED PRODUCTION

Modernization and mechanization of heat processing systems speed production, give uniformity of product, improve quality, and reduce your manufacturing costs. General Electric can supply materials handling equipment, atmosphere producers, instruments, quenching equipments and furnaces or induction heaters to give you "one source" responsibility for your heat treating line.



FACTORY ASSEMBLY REDUCES YOUR INSTALLATION TIME

General Electric can completely assemble large furnaces in its Shelbyville, Indiana plant. This means that when you buy from General Electric you can have your piped and wired furnace on the line more quickly and with lower over-all first cost. Experienced furnace builders handle every step of construction and General Electric provides either supervision or complete installation at your plant.

Progress Is Our Most Important Product

GENERAL ELECTRIC

up to 16 in. diameter swing and up to 7 ft. long. No jigs or fixtures are used because the main journals are lowered directly onto drive belts that both support and rotate the workpiece. Crankshaft is shot peened completely by two oscillating nozzles as they travel the length of the crankshaft for one round trip. The nozzle carrier is driven by a helicoid conveyor used as a shotproof lead screw. An air wash shot conditioner removes broken shot and dust.

For further information circle No. 241 on literature request card, page 48-B.

Testing Machine

A 1,000,000-lb. capacity super "L" hydraulic universal testing machine with four screw columns has been announced by the Tinius Olsen Testing Machine Co. Designed for testing complete aircraft sections, this machine has a 63-in. clearance between screws,

and accommodates specimens up to 18 ft. high in tension or compression. Its hydraulic loading system has a full 18-in. stroke. Four separate ranges, all with a common zero, are indicated on the color-coded dial. These ranges are 1,000,000, 500,000, 100,000 and 50,000 lb. The range can be changed at any time during the test.

For further information circle No. 242 on literature request card, page 48-B.

Hardness Tester

Steel City Testing Machines, Inc., has announced their appointment as exclusive U. S. distributor for the Penetrascope portable hardness tester, manufactured in England. The design, procedure of using the tester, and results obtained all conform to the A.S.T.M. E 92-57. The Penetrascope weighs approximately 18 lb. It can be used for testing a wide range of materials from thin metal strips to large mill rolls or cylinders. Tests can be made on profiles, recessed surfaces and gear teeth.

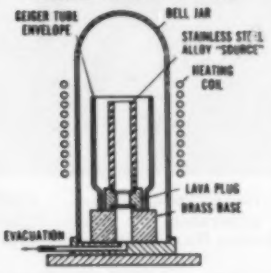
For further information circle No. 243 on literature request card, page 48-B.

The Lepel Line of induction heating equipment represents the most advanced thought in the field of electronics as well as the most practical and efficient source of heat yet developed for industrial heating.

If you are interested in induction heating you are invited to send samples of the work with specifications. Our engineers will process and return the completed job with full data and recommendations without any cost or obligations.

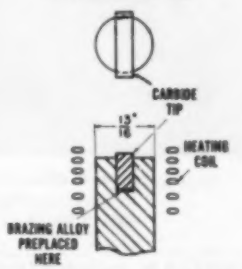
TYPICAL INDUCTION HEATING APPLICATIONS

METAL VAPOR COATING



The manufacture of Geiger Tubes requires a vapor coating of stainless steel inside of the glass envelope. The glass envelope is positioned inside of a bell jar which is connected to evacuation equipment. After evacuation, induction heating coil-shown in position over bell jar heats the stainless steel source to high temperature causing vaporization. Condensation occurs on glass walls of the tube.

CARBIDE TIPS BRAZED TO GRANITE DRILLS



The drawing shows a cabride tip being brazed in the milled recess of a drill. High temperature brazing alloy is preplaced as indicated. Proper spacing of the turns of the heating coil extends the transition zone to avoid metallurgical notch and thereby fatigue failure. In a production set-up, the heating cycle can be pre-set so that every drill will be uniformly processed.

SELECTIVE HARDENING OF RAIL GROOVE

V-grooves in steel rails are selectively hardened by the coil shown. Heating and quenching occur progressively as the rail moves through the coil and a quench ring.

Electronic Tube Generators from 1 kw to 100 kw
Spark Gap Converters from 2 kw to 30 kw

WRITE FOR THE NEW LEPEL CATALOG . . . 36 illustrated pages packed with valuable information

All Lepel equipment is certified to comply with the requirements of the Federal Communications Commission.

LEPEL HIGH FREQUENCY LABORATORIES, INC.
55th STREET and 37th AVENUE WOODSIDE 77 NEW YORK CITY N. Y.

Inconel alloy retort "cracked" natural gas in endothermic gas generator for well over 2 years at the Modern Heat Treating Company, 15402 S. Broadway, Gardena, California. Still in serviceable condition, it is now being used for stand-by purposes.

Inspection reveals:

gas generator retort of Inconel alloy still serviceable after 7,488 hours at 1850°F

After 2 years service in a Calalloy Endothermic Gas Generator, the Inconel retort you see above was inspected. Inspection showed that the retort, made by California Alloy Products Co., Los Angeles, was still good enough for use as a stand-by! It was still serviceable after 7,488 hours at 1850°F!

There are two good reasons why Inconel* nickel-chromium alloy can provide long, dependable service like this:

1. Inconel alloy is strong at high temperatures and resists thermal and mechanical shock.
2. This high-nickel alloy resists corrosion at high service temperatures for exceptionally long periods of time.

Inconel alloy could be your answer to high maintenance costs in gas generator retorts . . . in other heat treating equipment, too. Such as: furnace radiant tubes, furnace trays, muffles and retorts of all kinds. What's more, all these parts can be easily formed and welded when you specify Inconel alloy.

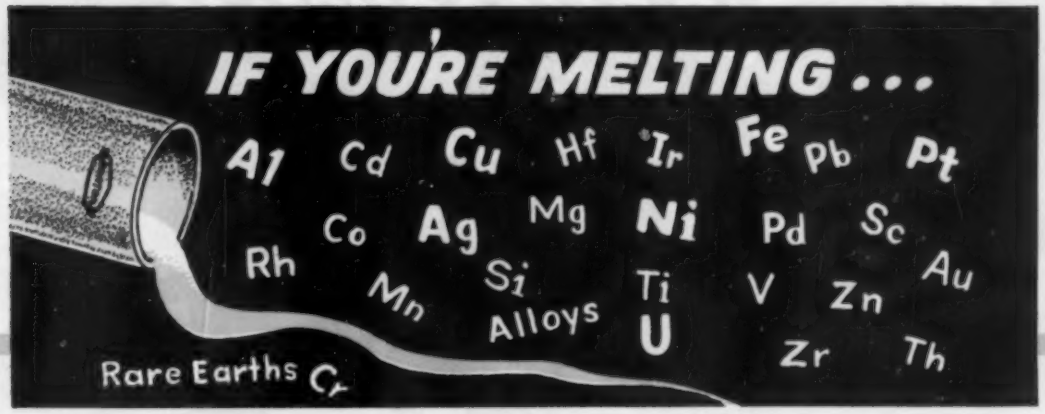
Tell your fabricator that he can get Inconel alloy right from warehouse stocks, in a wide variety of wrought mill forms. Tell him to look under "Nickel" in the classified directory for his nearest supplier.

And write for 20-page booklet "Keeping Costs Down As Temperatures Go Up." It gives complete information on how Inconel alloy can be of service to you. Write:

*Registered trademark

The International Nickel Company, Inc.
67 Wall St. New York 5, N. Y.

INCO NICKEL ALLOYS



Norton crucibles, available in many materials, meet a wide range of needs

HEAVY WALL CRUCIBLES

Furnace Sizes in Pounds	Outside Diameters	Wall Thicknesses	Over-All Heights
½ to 300	1⅛" to 12¼"	⅛" to ⅜"	3½" to 16½"

Materials Available

ALUNDUM*	"A" 99% Alumina	All Sizes Shown	ZIRCONIA	"H" Fused Stabilized Zirconia	All Sizes Shown
CRYSTOLON*	"G" First Quality Silicon Carbide	All Sizes Shown	THORIA		½ to 50 lbs.
CRYSTOLON	"N" Nitride Bonded Silicon Carbide	All Sizes Shown	URANIA		½ to 50 lbs.
MAGNORITE*	"K" 97% Fused Magnesia	All Sizes Shown			

LIGHT WALL CRUCIBLES

Furnace Sizes in Pounds	Outside Diameters	Wall Thicknesses	Over-All Heights
½ to 50	1 3/32" to 5 13/16"	3/32" to 5/32"	3½" to 10 11/16"

Materials Available

ALUNDUM	"A" 99% Alumina	½ to 50 lbs.	ZIRCONIA	"H" Fused Stabilized Zirconia	½ to 50 lbs.
MAGNORITE	"M" 99% Fused Magnesia	½ to 50 lbs.	THORIA		½ to 17 lbs.

Norton crucibles are *engineered and prescribed* for a long list of metal melting operations. Available in a wide range of materials, sizes and types — as shown in the tables — they provide long, trouble-free service, protect your product purity and meet specific melting requirements.

Norton heavy wall crucibles, exceptionally strong and dense, are used for most induction furnace melting jobs. Thin wall crucibles, generally of lower porosity, are particularly suited for special and nuclear metallurgical processes. Their fine, smooth surface is particularly valuable for protecting high purity metals from refractory inclusions.

It will pay you to get further facts on this complete line of crucibles. For exact recommendations and all necessary details, contact your Norton Representative. Or write for new catalog, "*Norton Refractory Crucibles*," to NORTON COMPANY, 327 New Bond Street, Worcester 6, Mass.

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Making better products . . . to make your products better

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Selective Surface Heat Treating

When it comes to selective part surface heat treating, production executives and plant operating men have shown an unusual interest in Cincinnati equipment. For Cincinnati builds both induction and flame heat-treating machines. Highly versatile Inductrons and Flamatics can do such work as annealing, brazing, soldering, tempering, stress-relieving, shrink fitting—and meet your cost-per-piece requirements—on high production quantities or varied, small-lot runs.

For information, call in a Meta-Dynamics Division field engineer. Backed by the resources of Cincinnati's completely staffed and equipped heat engineering laboratories, your needs will be analyzed, your parts "test run", and specific, unbiased recommendations made. Of course, there's no obligation.

Built in 15, 30 and 50 KW capacities, the new Cincinnati Inductron operates at frequencies up to approx. 1000 KC for faster heating, thinner case, greater freedom from scale and distortion. Write for Catalog No. M-1993.

New Cincinnati Flamatic shown equipped with rotary spindle unit. "Building-block" construction adapts the Flamatic to an extremely wide range of flame heating applications. Write for Catalog No. M-2015.

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META-DYNAMICS DIVISION
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Cincinnati 9, Ohio, U.S.A.

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APPLICATION and EQUIPMENT new literature

244. Air Washers
Bulletin No. 256 on acid-proof air washers for ventilation systems. Construction and accessories. *Automotive Rubber*

245. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

246. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

247. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

248. Alloy Steels
Article on use of chromium-molybdenum-vanadium steel for service at elevated temperatures. Chemical composition, mechanical properties. Vancoram Review, V. 13, No. 1. *Vanadium Corp.*

249. Aluminum Alloys
File on high-strength aluminum alloys gives advantages, applications, properties. *Frontier Bronze Corp.*

250. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

251. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

252. Ammonia
18-page booklet on ammonia cylinder installations for metal treating. Physical and chemical properties. *Armour*

253. Ammonia
New 6 and 4-page bulletins on ammonia storage units and nitrogen generator. *Hamler Industries, Inc.*

254. Barrel Finishing
New 8-page Bulletin No. 158 on equipment for precision barrel finishing. *Lord Chemical Corp.*

255. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

256. Blast Cleaning
Complete information on Malleabrasive for cleaning and finishing. *Globe Steel Abrasive*

257. Boron Stainless
8-page booklet on composition, structure, corrosion resistance, welding and mechanical properties of 1% boron stainless steel. *Superior Steel*

258. Box Furnaces
New Bulletin 315 on box and muffle furnaces. Five different models for analysis, control and production in chemistry, metallurgy and manufacturing. *Burrell*

259. Brazing
28-page catalog of brazing and soldering equipment with suggestions on setting up brazing lines to fit the product being joined. *C. M. Kemp*

260. Brazing
8-page bulletin S-1050 on production brazing and soldering with automatic machines. Construction of custom models. *Selas*

261. Buffing Compounds
Bulletin B-7 lists various compounds and gives applications. *Apothecaries Hall*

262. Burner
New Bulletin 109 on combination gas and oil burners. Description and output data. *Thermal Research & Engineering*

263. Burners
New Buzzer Catalog No. 1570 describes industrial gas burners, furnaces and accessories for heat treating, metal melting, soldering and drying. *Charles A. Hones*

264. Burners
New Bulletin 48.32 on flat flame gas burners. Characteristics, applications. *North American Mfg.*

265. Calibration
New Bulletin 159 on proving rings in weighing and force measuring systems. Their uses, construction and operation. *Morehouse Machine*

266. Carbides
15 data sheets on Carmet carbide grades. Typical applications, analysis, physical characteristics and grain structure. *Allegheny Ludlum Steel Corp.*

267. Castings
New 24-page folder on aluminum permanent mold and sand castings. Application, specifications, physical properties and characteristics. *Permold Co.*

268. Chemical Etching
10-page Bulletin 90 on precision etching of metal parts by chemical and electrolytic means. *Superior Tube*

269. Chromate Coatings
Data sheets on Luster-On 50 conversion coating for manual or automatic plating. Bath make-up, operating conditions, typical cycle. *Chemical Corp.*

270. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

271. Coated Metals
New bulletin on roll coating shows how it is done and includes samples. *Roll Coater, Inc.*

272. Coated Pipe
4-page folder on new plastic-coated steel pipe and tubing. How it solves the problem of pipeline corrosion. *Republic Steel*

273. Cobalt-Base Alloys
New 16-page booklet on Haynes Stellite alloy No. 31 for high-temperature properties. Chemical composition, physical and mechanical properties. *Haynes Stellite*

274. Controller
New Bulletin F-6314-3 on a self-contained, direct deflection type, indicating controller. *Wheelco Instruments*

275. Controllers
56-page bulletin on new series 500W pneumatic controller. Control principles and control modes available. *Bristol Co.*

276. Creep Testing
Bulletin 4420 describes long-time creep test machines, creep-rupture machines and relaxation machines. *Baldwin-Lima-Hamilton*

277. Crucibles
Bulletin C1-55 on crucibles for service to 2900° F. *McDanel Refractory Porcelain*

278. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

279. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

280. Descaling Stainless Steel
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

281. Drawing Dies
12-page bulletin on turks head, adjustable draw die. Basic types, development of turks head. *Fenn Mfg.*

282. Electric Furnaces
Data sheet describes and gives specifications of standard nonmetallic resistor furnaces. *Harrop Electric Furnace Div.*

283. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

284. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

285. Electron Microscopy
4-page bulletin on specimen preparation for electron microscopy. *RCA*

286. Electroplating
Bulletins on electroplated gold, rhodium, palladium, platinum, silver, nickel, and analysis of gold and gold alloy solutions. *Technic*

287. Endothermic Atmospheres
16-page reprint on endothermic atmospheres for heat treatment of steel. Effect of temperature on atmosphere. Calculating analysis. *Electric Furnace Co.*

288. Finishing Systems
New 12-page brochure on industrial finishing systems. Engineering, fabricating, installing. *Granco, Inc.*

289. Flame Hardening
New bulletin tells how flame hardening improves rolls. Chart shows ranges and depth of hardness. *Detroit Flame Hardening Co.*

290. Formed Shapes
26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

291. Forming
New 88-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

292. Freezer
Data on chest for use down to −95° F. for production and testing. *Revco*

ACHESON

dispersions digest

Reporting uses for

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COLLOIDAL GRAPHITE, MOLY-SULFIDE, VERMICULITE, AND OTHER SOLIDS

SUPERIOR CASTINGS, LONGER DIE LIFE ATTRIBUTED TO 'DAG' DISPERSIONS

Die casters and molders are expressing a growing preference for Acheson 'dag' brand colloidal dispersions. The consistent high quality of these products and the multiple benefits they offer have obsoleted most other mold cavity coatings. As outlined below, Acheson dispersions greatly aid in the manufacture of more uniformly sound castings having smoother surface finishes, facilitate metal flow and parting, and consequently extend the effective service lives of the dies and molds on which they are used.

Acheson 'Prodag®', spray-applied on permanent molds at Paragon Aluminum Corporation, has given them consistently higher quality castings and fewer rejects.

Better surface finish with 'Prodag' permanent mold coating is just one of the reasons why Paragon Aluminum Corporation, a Division of Detroit Harvester Company located at Monroe, Michigan, switched to this Acheson product. After four years of experimentation with other mold washes, Paragon chose 'Prodag' — Acheson semi-colloidal graphite in water — and has used it constantly the past seven years. The reasons for its choice are these; uniform consistency, excellent heat-transfer quality, and its hard, smooth, tenacious film which resists flaking and provides easier parting characteristics.

With about 95 per cent of its annual output of more than two million pounds of castings going to the automotive industry, Paragon must insist upon quality. 'Prodag' helps to maintain this standard. These parts for convertible automobile tops are precision-molded from both 355 and 319 aluminum alloy. Molds are preheated before each day's run to 600°F and the casting cycle maintains this temperature. The 'Prodag' dilution ratio is 1 to 4 parts water and is applied to the molds with a commercial spray gun. Aside from occasional touchup at points of greatest wear, this coating lasts through the entire run. Because of the physical contours involved in these comparatively small, light castings, they require rapid cooling in certain areas to insure uniform strength. The 'Prodag' coating — with its proven fast heat transfer ability — allows the castings to cool without breaks or pinholes. And by parting more easily, the high-finish castings which result have given Paragon Aluminum products wide acceptance in this demanding industry.

Typical parts cast at Paragon Aluminum include these automobile convertible top braces. More uniform strength, better finish, and fewer rejects result from this company's use of Acheson 'Prodag'.

If you have a metal casting problem, call in your Acheson Service Engineer. Or if you prefer, write direct for additional information contained in our Bulletin No. 425. Address Dept. MP-88.

'dag' and 'Prodag' are trademarks registered in the U. S. Patent Office by Acheson Industries, Inc.

Colloidal graphite increases die life because of its stability at high temperatures, excellent lubricating qualities, and its ability to prevent adhesion and the scrubbing effect of hot metal. This cannot be said of conventional petroleum compounds which either decompose rapidly at temperatures above 300°F or do not possess the required lubricity necessary under good die casting procedures. It will not volatilize when in contact with the hot metal and cause pock marks due to gas formation. It will perform when present in extremely thin films which will not affect dimensions or cause discoloration of the parts being cast. And since it does not volatilize or otherwise be destroyed in the casting process, it does not need to be applied as often as other lubricants. This fact alone has often increased production as much as 25%. Investigate the use of an Acheson colloidal dispersion in solving your die casting problem . . . *It probably is the very answer you need.*

ACHESON *Colloids Company*

PORT HURON, MICHIGAN

A division of Acheson Industries, Inc.

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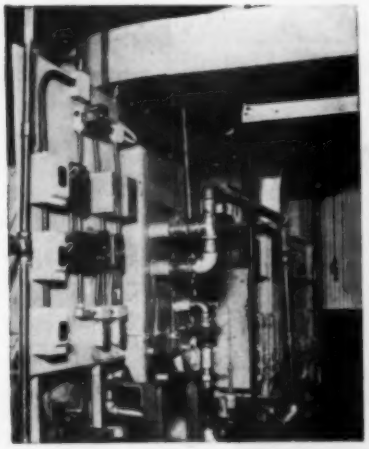

NIAGARA *Aero*
HEAT EXCHANGER
***quickly* pulls down the initial peak load of heat in quenching... and saves cooling water**

● You gain in accurate control of quench bath temperatures and quickly effective capacity to handle initial peak load of heat in quenching. You prevent production set-backs, increase the output of your heat treating department, prevent oil fires, save losses from rejected parts.

Niagara *Aero* Heat Exchangers give you this control in both furnace and induction hardening methods. They prevent both over-heating and over-cooling of the quench bath. Hundreds of heat treaters know they prevent many troubles, constantly improve quality and increase production.

They quickly pay for themselves by saving cooling water coils and extend your quench capacity without extra water or cooling tower.

Write for Bulletins 120 and 132 giving complete information.

NIAGARA BLOWER COMPANY
Dept. MP-8, 405 Lexington Ave.
NEW YORK 17, N. Y.
District Engineers in Principal Cities of U. S. and Canada

293. Furnace
New bulletin on basic principles of electric furnace design. Cutaway models of 8 furnaces. Cost factors. *Holcroft*

294. Furnace Elements
24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div., Carborundum*

295. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric*

296. Furnaces
Data on line of melting, heating and heat treating furnaces for ferrous and nonferrous metals. *Loftus Engineering*

297. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

298. Furnaces
Lists of surplus furnaces for sale. *Joe Martin Co.*

299. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

300. Gas Blenders
New Bulletin GB 10-57 on machine to control gas mixing. *Gow-Mac Instrument*

301. Graphite
20-page brochure on significance of graphite as electrodes, anodes, molds, and specialities in electrometallurgy and electrochemistry. *Great Lakes Carbon*

302. Hardness Numbers
Pocket-size table of Brinell hardness numbers. *Steel City Testing*

303. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

304. Hardness Tester
Bulletin A-16 on micro-reflex hardness testers. Loads to 3000 gr. Zeiss optical system. *Gries Industries, Inc.*

305. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

306. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

307. Hardness Testers
20-page bulletin on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument*

308. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion Div.*

309. Heat Treating
Monthly bulletin on used heat treating and plating equipment available for immediate delivery. *Metal Treating Equipment Exchange*

310. Heat Treating
12-page bulletin on heat treating equipment. Applications and special features of 19 different types of furnaces including shaker hearth, conveyor, high vacuum, elevator-type brazing. *Pacific Scientific*

311. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

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Welders can really pour it on with P&H Iron-Powder Electrodes! Faster deposition and superior weldability make them easy to handle in any position—enable operators to produce X-ray welds by simply dragging the electrode. Added benefits: a minimum of spatter and low stub loss.

Welds are smooth and practically self-cleaning — possess high strength with greater impact at low temperatures. Get Bulletin R-29. Write Dept. 302E, Harnischfeger Corporation, Milwaukee 46, Wisconsin.

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SWIFT'S FLEXAL 2

THIS "LIGHT" METALLIC STEARATE WAS THE *MISSING LINK* IN AN IMPORTANT DEVELOPMENT

Your process might be the next to benefit

Until recently, Flexal² was the elusive *missing link* in a Swift research program aimed at the development of a superior and highly heat resistant water insoluble metal processing lubricant.

Flexal² is a "light" metallic powder of extremely uniform consistency. It has exhibited excellent heat stability and has shown long, effective and *economical* service life as an anti-friction agent for the processing of ferrous metals.

Swift's success with this program has revealed a *variety* of usages for Flexal² which has led to the development of a whole *family* of Flexals. The combination and range of physical and chemical properties offered by this new family of products will be of interest to anyone seeking a: *colloidal agent • stabilizer • process lubricant • parting agent • high speed and anti-friction compound • carrier • plastic additive • extender—and many other uses.*

The Flexals are available in production quantities or on sample or trial order. The benefit of Swift's technical experience with these remarkable products is available to help you. Just write for details. Swift & Company, Soap Dept., 4115 Packers Ave., Chicago 9, Illinois.

GENERAL PROPERTIES:

CHEMICAL

moisture—from 1% to 3% max.
titer range—10° C to 60° C
iodine number—3% max to 95
melting point—150° F to 800° + F
storage life—completely stable
molec. weight—(approx.) 288 to 700

PHYSICAL

form—amorphous to powder
color—gray to white
odor—neutral
solubility—versatile; Flexals can be either soluble or insoluble in water or solvents, depending upon need.

Swift
103rd YEAR

To Serve Your Industry Better

312. Heat Treating

New Bulletin SC-171 on furnaces, soaking pits, annealers, batch units for heat treating, melting, investment casting aluminum and other light alloys. *Surface Combustion*

313. Heat Treating Belts

Catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

314. Heat Treating Equipment

New 24-page Catalog 54 on light-weight processing and heat treating equipment. *Pressed Steel Co.*

315. Heat Treating Fixtures

32-page catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat treating equipment, pickling equipment. *Rolock*

316. Heat Treating Fixtures

New 16-page Catalog M-7 on heat treating and corrosion resistant alloy fabrications. *Wiretex Mfg. Co.*

317. Heat Treating Furnaces

Folder on industrial furnaces. Continuous designs. Insulation. *Pacific Industrial*

318. Heat Treating Supplies

Data sheets on carburizing, hardening, tempering, nitriding salts, metal cleaning and rust prevention materials. *Heatbath*

319. Heat Treatment

Bulletin 200 on car hearth, rotary hearth, pit, roller hearth, belt, chain, pusher, and "hi-head" furnaces. *R-S Furnace*

320. Heaters

Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

321. High-Strength Steel

Folder on medium manganese copper-bearing high strength steel. Properties. Corrosion resistance. *Youngstown Sheet & Tube*

322. High-Temperature Alloy

Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys*

323. High-Temperature Alloys

20-page booklet on nine alloys for elevated temperature service. Data sheets cover analysis, physical constants, mechanical properties, heat treatment, workability, machinability, welding, corrosion resistance. *Carpenter Steel*

324. High-Temperature Lubrication

Bulletin 423 on colloidal graphite and molybdenum disulfide dispersions and their use for high-temperature lubrication. Case histories. *Acheson Colloids*

325. Impact Testing

Bulletin on machine for Izod, Charpy and tension testing. *Riehle*

326. Induction Furnace

4-page folder on combination induction melting and holding furnace and automatic pouring unit. *Ajax Engineering*

327. Induction Hardening

Bulletin M-1938 on induction hardening machine gives advantages and application of system. *Cincinnati Milling Machine*

328. Induction Heaters

8-page bulletin EH 57-6 on electronic induction heaters. Specifications, basic components, guide to brazing and soldering and frequency selection chart are included. *Magnethermic*

329. Induction Heating

Folder 15C8053C gives advantages of induction heating and specifications and dimensions of induction heater. *Allis-Chalmers*

330. Induction Heating

Need for ground detectors on high frequency induction furnace discussed in Inducto Metal Melting Newsletter, No. 5. *Inductotherm*

331. Induction Heating

High Frequency Review contains article on high temperature fatigue tests using induction heating. *Lepel High Frequency Laboratories*

332. Induction Heating

60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

333. Induction Heating

Brochure on induction heating furnace. Frequency chart. *Pittsburgh Induction Heating Co.*

334. Industrial Equipment

12-page catalog on finishing systems, cleaning, pickling, rustproofing equipment, ovens, conveying equipment. *R. C. Mahon Co.*

335. Instruments

6-page Bulletin 11E on mechanical force gage for measuring pressure, tensile or torque. *W. C. Dillon*

336. Instruments

32-page Catalog 20-10 on electronic self-balancing instruments for indicating, recording, controlling. Instruments described and diagrammed. Principles of operation. *Foxboro*

337. Low-Alloy Steel

60-page book on high-strength low-alloy steel, properties, fabrication and uses. *U. S. Steel*

(Continued on page 48A)

Testing Problems?
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• COMPRESSION • SHEAR
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will solve them all!

You can make *any* workbench a testing area with a DILLON Model L Bench Tester. This low cost instrument precision-checks metal, plastics, wire, rubber, springs, etc. Operates in tensile, compression, transverse or shear! Handles round, flat or special shapes. Hand wheel or motorized. Equipped with max. indicator. 7 interchangeable gauges. For materials up to 125,000 lbs. PSI tensile. Wide range of gripping fixtures. Also available on stand.

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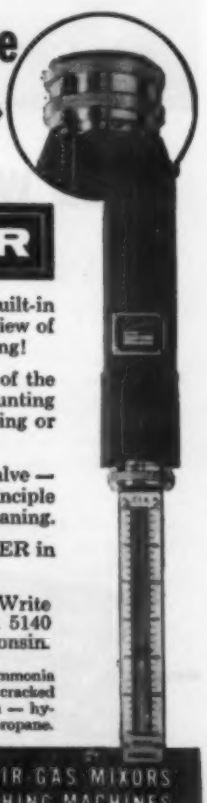

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FLO·METER

With the Waukee FLO-METER'S built-in Valve, you adjust the gas flow in full view of the scale. You can see what you're doing!

The Control Valve is an integral part of the FLO-METER, designed for panel mounting and simple piping. No extra valve piping or installation. Saves time and money.

It's a Waukee-designed and built valve — sturdy, simple, smooth. Needle-valve principle for accuracy, sensitivity, and easy cleaning.

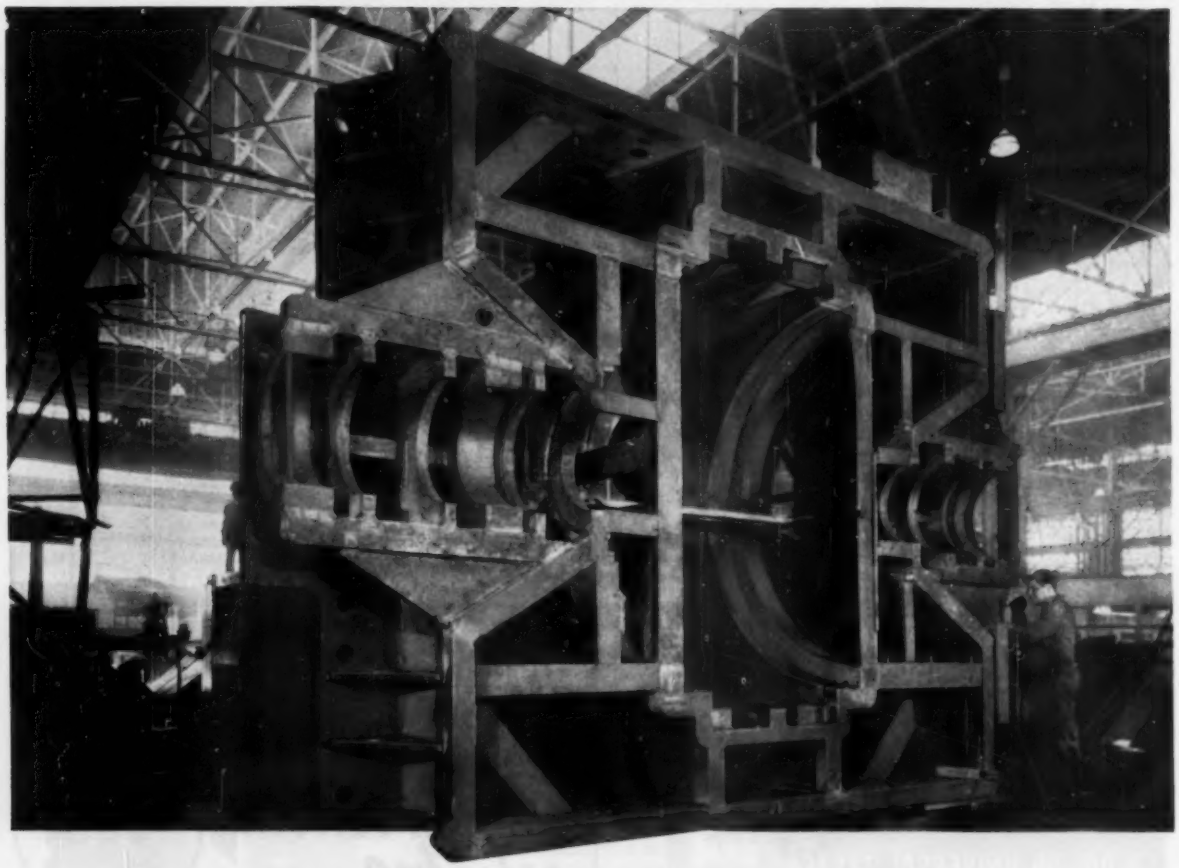
And you can still clean the FLO-METER in 5 minutes *or less!*

Complete information in Bulletin 203. Write for it. Waukee Engineering Company, 5140 North 35th Street, Milwaukee 9, Wisconsin.

For measuring: air — ammonia — dissociated ammonia — argon — butane — city gas — endothermic cracked — exothermic cracked — forming gas — helium — hydrogen — natural gas — nitrogen — oxygen — propane.

Waukee FLO METERS • AIR GAS MIXORS
INDUSTRIAL WASHING MACHINES

STEEL-WELD FABRICATION . . .



Less Weight in Heavy Machinery Components!

The 100-Ton Weldment illustrated above, in process of fabrication, is the base unit of a housing for a 300,000 kw Steam Turbine. It is a typical example of Mahon's capabilities in the field of heavy plate fabrication.

When you consider Steel-Weld Fabricated components for processing machinery, machine tools, or other types of heavy mechanical equipment, you, too, will want to discuss your requirements with Mahon engineers; because, in the Mahon organization you will find a unique source for weldments or welded steel in any form . . . a fully responsible source with a long and enviable performance record, and unusual facilities for design engineering, fabricating, machining and assembling.

See Sweet's Product Design File for information, or have a Mahon sales engineer call at your convenience.

Use WELDED STEEL for 100% Predictability and Greater Strength with Reduced Weight!

THE R. C. MAHON COMPANY • Detroit 34, Michigan

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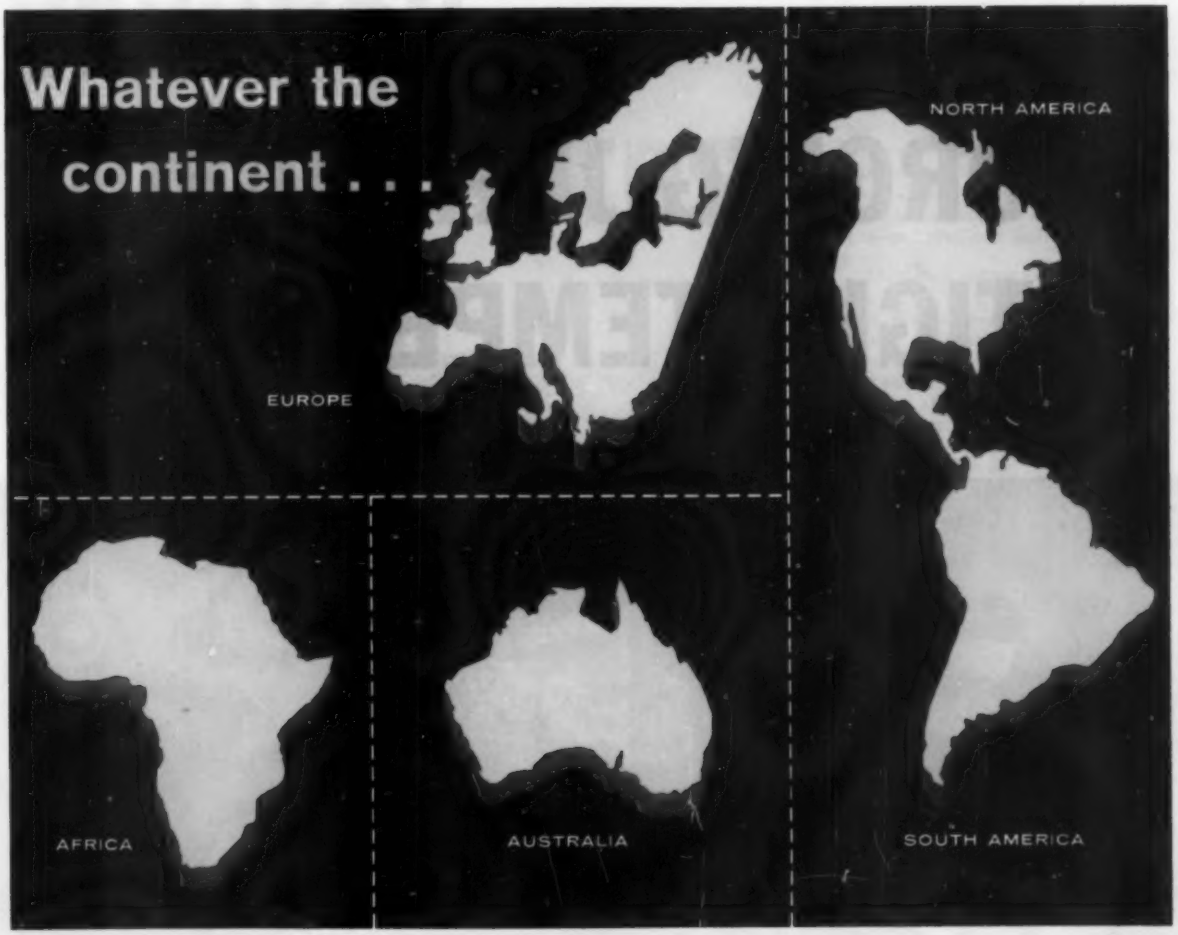

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Shell Tellus Oils—for closed hydraulic systems

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Shell Dromus Oils—soluble cutting oils for high-production metal working

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Shell Voluta Oil is a stable high-speed quenching oil that proves ideal for use in both static and circulating quenching systems.

Voluta® Oil offers two unique characteristics: (1) It remains stable at temperatures up to 180°F. with no appreciable sludge formation. (2) It permits safe, rapid quenching of parts which ordinarily have a tendency to distort.

Voluta Oil is available on a world-wide basis, and you can be sure your customers *abroad* will get the same performance from your quenching equipment that your domestic customers rely upon. Write for complete information to Shell Oil Company, 50 West 50th Street, New York 20, N. Y.,or 100 Bush Street, San Francisco 6, California.

SHELL VOLUTA OIL

SHELL

HOW KEY FORGING JET TURBINE TIGHT TEMPERATURE

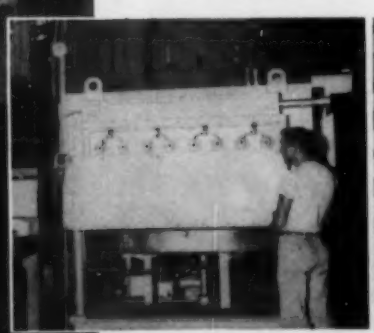
ELECTRIC FORGING FURNACES at Thompson Products, Inc (Harrisburg plant), both General Electric and Hevi-Duty units, are equipped with GLOBAR heating elements to assure precise temperature control of alloys used for compressor and turbine vanes and blades. Shown above is one of several aisles in which both furnaces and forging presses are located.

PLANT BLADES KEEPS CONTROL

Jet Division of Thompson Products, Inc. uses GLOBAR® Delta electric elements for forging and heat treating

High temperature steels for a jet's turbine blades can be critically affected by variable temperatures during heating. That's why Thompson Products, Inc.—one of the largest manufacturers of rotating and non-rotating jet engine parts in the world—uses GLOBAR Delta electric heating elements. They assure close, precise temperature control to maintain the alloy's metallurgical properties.

At its Harrisburg, Pa. plant (shown here), Thompson Products, Inc.—long noted for its advanced techniques and materials—converts bar stock to completed turbine blades. According to Mr. Robert A. Buente, Superintendent of Maintenance, "furnaces equipped with GLOBAR elements do an excellent job. If we ever go to higher production rates, we'll use more GLOBAR-type furnaces."



TERMINAL CONNECTIONS (left) for 8 GLOBAR elements are on a HEVI-DUTY furnace. Elements can be replaced without cooling the furnace or interrupting production. **STOCK OF GLOBAR** Delta silicon carbide electric heating elements (right) is kept on hand to assure fast replacement.

ECONOMIC advantages of electric heat:

There are many reasons why the use of GLOBAR Delta silicon carbide elements are economical as well as dependable, clean, safe, and quiet. There is no fire or explosion hazard, and exhaust and fuel storage facilities—and costs—are unnecessary.

Only with electric heat can heating cycles be precisely duplicated and temperatures accurately controlled, independent of the atmosphere. Product quality is improved and rejects sharply reduced. Electric furnaces and kilns are compact and space-saving. They can be located in the production line, thereby accelerating production and reducing costs per unit of product.

When evaluating heat source, remember that electric heat alone utilizes its full potential. You don't pay for waste BTU's that go up the stack. Consequently, overall operating costs are reduced, furnace maintenance held to a minimum.

Installation of Delta elements is simple, and element replacement is accomplished quickly without cooling the furnace or interfering with production.

Typical applications for GLOBAR Delta elements include furnaces and kilns for: heat treating, forging, sintering, brazing, annealing, melting, assaying, roasting, laboratory and research; ceramic firing of ferrites, titanates, steatites, glass to metal seals, electrical insulators, grinding wheels, refractories, whiteware, pottery and tile.

Find out how your operation could profit by using GLOBAR Delta silicon carbide electric heating elements. Your furnace builder can supply you with full details. The Carborundum Company, Refractories Division, Globar Plant, Dept. MP88, Niagara Falls, New York.

CARBORUNDUM

Registered Trade Mark

Memo on Metals

New Study Shows Crucible 56 Offers the Stability, Tensile and Yield Strengths Needed in 800—1000° F. Applications

A recent study considers three steels which show promise of solving the high temperature strength problems encountered in today's high speed flight.† These problems of maintaining structural strength at elevated temperatures are further complicated by the need for favorable strength/weight ratios.

Two of the steels are hot work types (Crucible 218 and 56) that are only now being considered for structural applications in aircraft. Crucible 56 is a relatively new steel, offering an unusually high level of stability at high temperatures. The chemistries of the three steels are as follows:

CHEMICAL COMPOSITION

Grade	C	CR	Ni	Mn	Mo	V	Si	Al
Crucible 56	.40	3.30		.60	2.75	.40	1.00	
Crucible 218	.38	5.20		.35	1.40	.50	1.10	
AISI 4340	.40	.80	1.80	.70	.25		.30	

Figs. A and B compare the tensile and yield strengths of the three steels at the exposure temperature. The curves show that both Crucible 56 and Crucible 218 proved superior in these tests. However, the hardness-tempering curve for Crucible 56 shows that it is more stable than the other analyses evaluated. Crucible 56 also offers higher hardness (and hence, strength) when tempered in the 1050-1100° F. range. As the comparisons indicate, it also has higher elevated temperature tensile and creep properties than Crucible 218, which is a conventional AISI type. In Fig. C, the isochronous (constant time) stress-strain curves illustrate the stability of Crucible 56 at the top of the service temperature range. With these curves it is possible to determine the stress at which creep becomes an important consideration.

For further details on Crucible 56 and other comparative data, send the coupon.

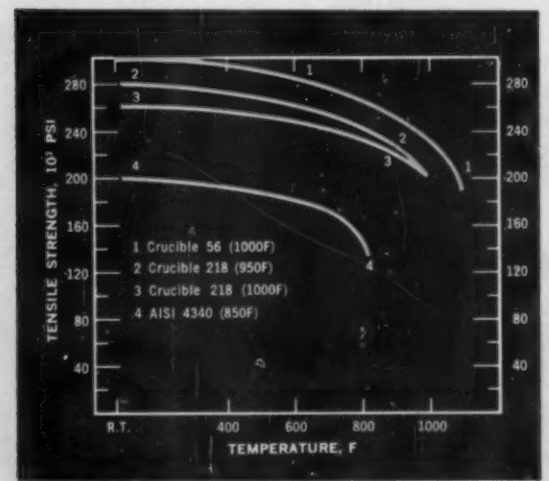


Fig. A. Tensile strength of various steels at exposure temperatures. Figures in parentheses are tempering temperatures.

†Although this study considers only aircraft applications, data given here may prove helpful in designing turbines, chemical processing and nuclear equipment, and other equipment where service temperatures ranging from 800-1000° F. are required.

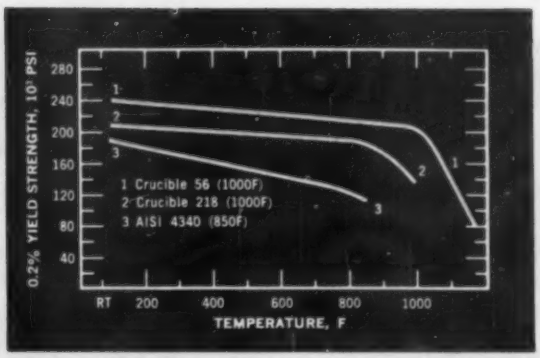


Fig. B. Yield strength (0.2% off-set) of various steels at exposure temperatures. Figures in parentheses are tempering temperatures.

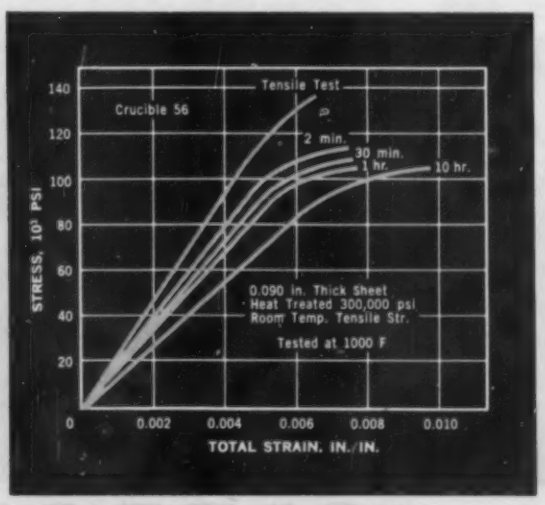


Fig. C. Isochronous stress-strain curves for Crucible 56 sheet show the outstanding creep properties of this steel which are higher than any other steel at 1000° F.

* high temperature strength
* vacuum melting
* cast properties of UHS-260

Compares properties of bearing steels produced by various melting techniques

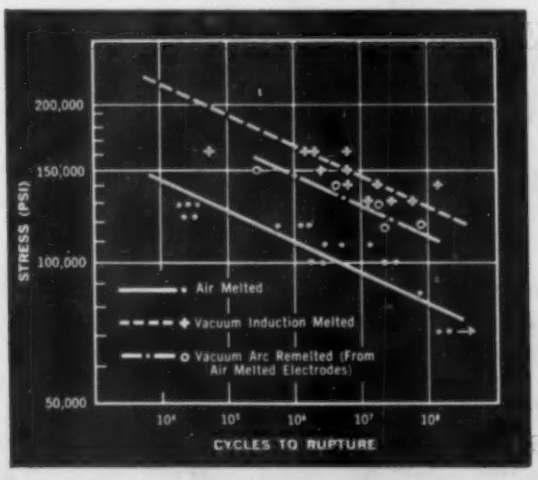
High vacuum technology has expanded considerably in recent years. The degree of improvement obtainable can be shown by comparing the properties of SAE 52100 produced by various melting techniques.

The following table gives gas content analyses of this chromium-carbon steel when produced by air melting (AM), air melting and vacuum arc remelting (AM + VAR), vacuum induction melting (VIM) and double melting (VIM + VAR):

Melting Technique	O(PPM)	N(PPM)	H(PPM)
AM	30	100	< 1
AM + VAR	7	70	< 1
VIM	5	3	< 1
VIM + VAR	3	3	< 1

Reduction in gas content is important, of course, because gases have varied detrimental effects on alloys. Oxygen increases transition temperature and forms various types of inclusions. Nitrogen effects aging, fatigue and stress rupture.

Similar improvement is obtained in cleanliness. (Inclusions strongly influence properties such as fatigue, impact and ductility.) Vacuum induction melted 52100 shows very small sulphide and oxide inclusions. Its background is extremely clean. Vacuum arc remelted 52100, made from air melted electrodes, also shows significant improvement over the air melted steel. Still further improvement is available with double melting.



Up to now, vacuum melted 52100 has been used mainly in bearings for jet engines, grinder spindles and instruments. It is credited with extending "B-10" life (the life at which 10% of the bearings fail) from 65 hours to 375 hours. Premature failures have been virtually eliminated. And the average number of production rejects of finished balls has dropped from 15% to 0.3%—savings that in some cases pay for the slightly higher cost of the vacuum melted alloy.

For more data on vacuum melted SAE 52100—or data on other vacuum melted ferrous and non-ferrous metals and alloys—send the coupon.

UHS-260 in cast form offers high strength with good ductility

New studies of the cast properties of UHS-260 should prove interesting to designers of structural parts for aircraft. In cast form at high temperatures, UHS-260 offers very high tensile strength with ductility equal to or better than transverse properties of the wrought form. Data from a preliminary report is given below. *For more complete information send the coupon.*

Grade UHS-260 Cast Properties —Preliminary Report

Nominal Composition

C	Si	Mn	Mo	Cu	Fe	Cr	Ni	V	Condition
0.35	1.50	1.35	0.30	–	Bal.	1.25	–	0.30	Hardened & Tempered

Mechanical Properties

	Test Temp °F.	Tensile Strength psi	Yield Strength psi	% Elong	% R.A.	Charpy Impact
Mean	–40°	265,000	218,000	6	10.5	7
High		268,000	226,000	6.5	15	8
Low		262,000	213,000	4	9	6
Mean	76°	260,000	217,000	4.5	12.5	7.7
High		265,000	241,000	6	16	8
Low		257,000	211,000	4	7	6
Mean	400°	266,000	191,000	5	7.3	11
High		269,000	205,000	6	10	13
Low		261,000	183,000	4	5	9
Mean	600°	237,000	162,000	9	18	11.3
High		240,000	172,000	10	23	12
Low		234,000	153,000	8	13	10
Mean	800°	200,000	147,000	9.6	29	12.3
High		232,000	179,000	13	42	13
Low		189,000	131,000	3	4	12

CRUCIBLE STEEL COMPANY OF AMERICA
Dept. EHO6, The Oliver Building
Mellon Square, Pittsburgh 22, Pa.

Gentlemen:

Please send me the following:

1. Crucible 56 Data Sheet_____ Comparative Data_____
2. Data sheet on vacuum induction melted SAE 52100_____
3. Data on other VIM metals_____
4. Further information on the cast properties of UHS-260_____

Name_____

Title_____

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"B&W Welded Tubing with special smooth ID finish keeps my fabrication problems to a minimum!

As a design engineer for hydraulic applications, I find that B&W Welded Carbon Steel Mechanical Tubing with special smooth ID finish offers outstanding benefits. The finished condition in which it comes to our plant reduces costs by eliminating a number of fabricating operations."

The uniform finish of this type of tubing means that for many hydraulic applications it can be used "as received" from the mill—eliminating such operations as grinding and polishing. Continuous quality control through every manufacturing operation—with ultrasonic testing supplementing accepted methods of inspection—makes sure that you get tubes matched to your end-use application. Ask Mr. Tubes, the B&W specialist—he can help you with any tube problem—or write for bulletin TB-428. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

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Seamless and welded tubular products, solid extrusions, seamless welding fittings and forged steel flanges—in carbon, alloy and stainless steels and special metals.

(Continued from page 41)

338. Lubricant
New 8-page Bulletin 304 on use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Molykote*

339. Magnesium
New 53-page book on wrought forms of magnesium. Includes 44 tables. *White Metal Rolling & Stamping Corp.*

340. Manganese
9-page article on electromanganese. Manufacturing procedures, product characteristics, uses. In Foote Prints, V. 28, No. 2. *Foote Mineral Co.*

341. Metal Finishing
New 30-page brochure on chemical milling. Advantages, engineering applications, operations involved. *Anadite, Inc.*

342. Metal Marking
New bulletin on all purpose electric pen to arc etch any metal. *Newage*

343. Metal Strip
New 8-page brochure on precision cold rolled strip from 0.100 to 0.0001 in. in a variety of ferrous and nonferrous alloys. *Precision Metals Div., Hamilton Watch*

344. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

345. Microscope
New Technical Bulletin HHS-2 on vacuum heating stage which permits specimens to be examined at temperatures ranging from room temperature to 2000° F. Application, specifications. *Unitron Instrument Div.*

346. Mixers
20-page booklet B-103 on fixed mounting propeller-type fluid mixers. Mixing capacities, standard sizes and speeds. *Mixing Equipment*

347. Molybdenum Alloying
Chart gives weight of ferro molybdenum addition needed by foundry for molybdenum contents in castings up to 1.50%. *Climax Molybdenum Div.*

348. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

349. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

350. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

351. Optical Parts
New 16-page Catalog L-117 on full line of optical parts. 28 tables. *Bausch & Lomb*

352. Oxygen
New 16-page brochure on equipment for production of oxygen and nitrogen in liquid or gaseous form. Also pumps, storage and converter tanks. *Superior Air Products Co.*

353. Photographic Films
Catalog of motion picture, radiographic and industrial films, photographic papers and luminescent chemical products. *DuPont*

354. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

355. Plated Strip
Bulletin on plated metal strip. Plating thicknesses and variations possible. *Sylvania Electric*

356. Plating
Data and specification sheet covering tin plating a wide range of nonferrous thin strip metals. *Somers Brass Co.*

357. Portable Pyrometer
New bulletin on potentiometer type portable pyrometer indicator. Construction, range, operation. *Thermo Electric*

358. Powder Metallurgy
Folder on tooling for powder metallurgy discusses high speed steels, die steels. *Vanadium-Alloys Steel Co.*

359. Precious Metals
Data on bright gold, bright silver, rhodium plating and salts. *Sel-Rex*

360. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

361. Presses
Metal Digest V-4, No. 2 on presses for specimen mounting and general laboratory work. *Buehler*

362. Protective Coatings
Folder 301 on industrial protective coatings of rubber, neoprene and other materials. *Arco Steel Fabricators*

363. Pyrometers
Data sheet 1E-1 on high-resistance indicating pyrometers. Special thermocouples for surface measurement, molten nonferrous metals, general immersion. *West Instrument*

364. Quenching
Bulletin 120 on use of heat exchangers to provide heat control in quenching bath. *Niagara Blower*

365. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

366. Radioactive Chemicals
24-page booklet describes radioactive chemicals and their uses. Lists those available. *Baker & Adamson.* See page 17.

367. Radiography
Reprint from Canadian Metalworking describes powerful gamma radiography machines which can be used to radiograph up to 10-inch sections. *Budd Co.*

368. Refractories
8-page catalog of super refractory shapes, tubes, insulators for use to 3500° F. *Morganite, Inc.*

369. Refractories
New 24-page booklet on refractory brick and other shapes. Technical data, tables, graphs, conversion charts. Properties. *Norton*

370. Resistance Alloy
8-page catalog of copper-nickel resistance wire. Physical properties, specifications resistance for 54 wire sizes and 31 ribbon sizes. *Hoskins Mfg.*

371. Resistance Material
16-page brochure on high-temperature electrical resistance heating material. Electrical, chemical and physical characteristics of new cermet material. *Kanthal*

372. Rust Prevention
Nine bulletins in one folder on rust prevention. Theory of corrosion. Applications. *Production Specialties*

373. Rust Preventive
New bulletin on wetting agent and emulsifier for use as a rust preventive and corrosion inhibitor. *Swift & Co.*

374. Salt Bath Carburizing
5-page booklet on liquid carburizing with advantages and disadvantages of the salt bath process. *American Cyanamid*

375. Salt Baths
Reprint No. 149 on salt bath furnace treatment of landing gears. Equipment used, advantages. *Ajax Electric Co.*

376. Saws
Catalog C-55 describes 35 models of metal-cutting saws. *Armstrong-Blum*

377. Sodium
28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

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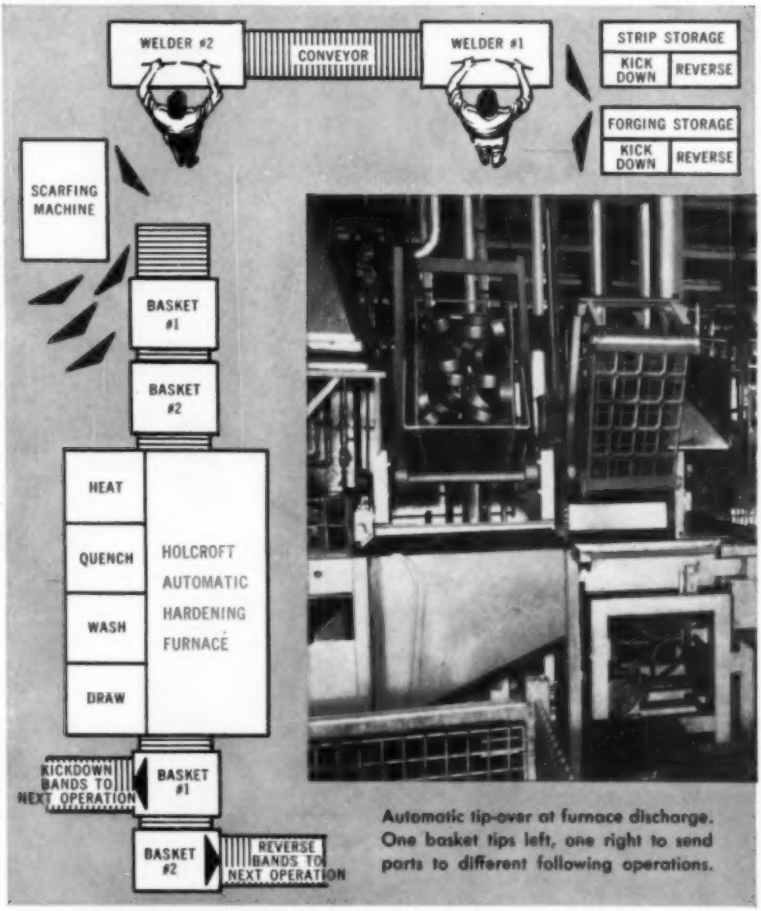

Automatic tip-over at furnace discharge. One basket tips left, one right to send parts to different following operations.

Fully automatic hardening furnace by HOLCROFT requires no operator...

Sorts hardened parts automatically

In this transmission parts line two welding operations, scarfing, hardening and two sorting operations are handled by just two welding operators and a Holcroft automatic hardening furnace. The operator at the second welding station distributes his output into two baskets, one for kickdown bands and one for reverse bands. The Holcroft furnace collects both baskets, heat treats the parts and *automatically* sorts them onto two conveyors which carry them to separate additional operations, all without rehandling of the parts or attention of any kind.

Holcroft engineered and built eight of the furnaces in this modern automotive transmission plant and every one of them shows the same leadership in design concept and quality of construction. The result of this leadership is clear; top quality production, lowest possible operating costs, long, trouble-free life. These are the true measure of heat treating economy. Next time you have a heat treating problem, call on Holcroft engineers to show you how to get truly economical production.

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PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

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Wheelco Instruments

Wheelco Instrumentation Among Top-Quality Features of Lucifer "Space Saver" Furnaces

Model 8000 recorder-controller provides hardening temperatures up to 2300° F, while draw furnace temperatures up to 1250° F are controlled by Model 292 Capacitrol.

Two electric furnaces in the floor space of one, each independently controlled so that hardening and drawing operations can be performed at the same time — that's the "Space Saver" line by Lucifer Furnaces, Inc., Neshaminy, Pa. Wheelco instrumentation makes an important contribution to peak-quality performance on the "Space Saver" series just as it does through the complete Lucifer line. Modern furnace design and Wheelco instrumentation go hand in hand.

Builders of top-quality furnaces and discriminating users, as well, know that the complete line of Wheelco instruments offers both the control form and degree of accuracy required by a particular installation. Put Wheelco to work on your job by contacting your nearby, broadly experienced Wheelco field engineer.

BARBER-COLMAN COMPANY

Dept. H, 1518 Rock Street, Rockford, Illinois, U.S.A.

BARBER-COLMAN of CANADA, Ltd., Toronto

378. Spectrochemical Analysis
28-page brochure on basic fundamentals of spectrochemical analysis. Methods, instruments, accessories described. Bibliography of reference material. *Jarrell-Ash*

379. Spectrographic Sources
4-page bulletin 35A on spectrographic source unit gives data on three units available. *Baird Atomic*

380. Springs
8-page bulletin on spring design. Stress and deflection formulas for various types of springs. Physical properties of commonly used spring materials. *Associated Spring*

381. Stainless Fasteners
24-page catalog 56-A lists sizes and types. 7000 items included. *Star Stainless Screw*

382. Stainless Steel
36-page bulletin on effect on properties of processing at different temperatures. *International Nickel*

383. Stainless Steel
28-page book on Type 430 nickel-free chromium stainless. Properties, surface characteristics, fabrication, applications. *Washington Steel Corp.*

384. Stainless Steels
10-page booklet contains charts, graphs, data on cold rolled mechanical properties, elevated temperature properties, physical properties and corrosion resistance of chromium-nickel manganese steels. *Allegheny Ludlum*

385. Stainless Tubing
12-page brochure on stainless steel heat exchanger and condenser tubes. Manufacture, chemical composition and analysis. *Republic Steel*

386. Temperature Measurement
New 6-page Data Sheet E-33(3) on instruments for highly accurate temperature measurements. Specifications and applications. *Leeds & Northrup*

387. Test Specimens
Data on machine for cutting test specimens to ASTM specifications. *Sieburg Industries*

388. Testing Machines
Revised Bulletin 47 on Super "L" hydraulic universal testing machines. Loading systems, indicating systems, capacities. *Tinius Olsen Testing Machines*

389. Thermocouple Insulators
New Bulletin No. 300-56 on complete line of thermocouple insulators. Dimensions, sizes, types of insulators. *Claud S. Gordon*

390. Thickness Gage
Folder on pocket-size gage. How to use it. *Ferro Corp.*

391. Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

392. Titanium
New 32-page Titanium Engineering Bulletin No. 6 on titanium welding techniques. Procedures, mechanical properties of weldable grades. *Titanium Metals Corp. of America*

393. Titanium Powders
Data on high purity and commercial titanium powders. *Hawkridge Metals*

394. Tool and Die Steels
26-page book on six oil and air hardening steels for high-production tools and dies. Uses. *Bethlehem*

395. Tool Steel
Chart gives stock sizes, analyses and properties of A2 and O1 precision ground tool steel. *Uddeholm*

396. Tool Steels
New 12-page booklet on tool steels for forging operations. Basic forging operations, equipment. Heat treatment of steels for hot forging. *Crucible Steel*

397. Transfer Lines
New Bulletin 4-80 on vacuum-jacketed transfer lines for transfer of low temperature liquid oxidizers. *Rochester Div. CEC*

398. Tubing
New 6-page Bulletin TB-428 on cold-drawn mechanical tubing. Applications and advantages. *Tubular Products Div., B. & W.*

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New book on production of seamless and welded tubing. Forging and fabricating operations. *Ohio Seamless Tube*

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12-page booklet on tungsten coil products for electronic and lighting applications. *Sylvania Electric Products, Inc., Tungsten & Chemical Div.*

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New Data Sheet No. 1500 on ultrasonic cleaners. Types of soil that can be removed. *Narda Ultrasonics Corp.*

402. Ultrasonic Cleaning
New 24-page Bulletin S-200 explains practical applications and basic principles of ultrasonic cleaning. Design of equipment. *Branson*

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Folder on vacuum melted cobalt, ferrous and nickel-base alloys. Quality control. *Cannon-Muskegon Corp.*

404. Vacuum Furnaces
New 8-page Brochure GED-3599 on vacuum-arc melting as a production technique. Design of furnaces, components, controls and instrumentation. *General Electric*

405. Vacuum Furnaces
Bulletin 557 on vacuum furnaces for temperatures to 2100° F. Dimensions of pit and bell types. *Hevi Duty Electric*

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New 28-page Brochure 1-2 on high vacuum impregnating, drying, degassing, and filling techniques. Electrical and physical characteristics. *NRC Equipment*

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28-page catalog No. 752 contains specifications, tables of formulas, constants and conversion factors. Maintenance procedures. *F. J. Stokes*

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New 22-page booklet on welding positioners. Case histories. *Harnischfeger*

409. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

410. Welding Stainless
New 12-page booklet—a guide to better welding of stainless steels. In question and answer form. *Arcos*

411. Welding Titanium
New 8-page technical brochure on the arc welding of titanium. Lists grades of pure titanium and titanium alloys which can be welded. Basic problems discussed. *Mallory-Sharon Metals*

412. X-Ray Films
6-page folder on industrial X-ray films and processing chemicals. Exposure characteristics. Selection of best film for each job. *Ansco*

413. X-Ray Microscope
New catalog includes micrographs, theory of operation and technical details. *General Electric, X-Ray Dept.*

414. Zinc Coating
New 8-page booklet on zinc-coated steel sheets. Fabrication, uses, advantages in heating, ventilating and air conditioning. *Weirton Steel*

415. Zirconium
8-page brochure on zirconium's corrosion resistant properties. Applications based on this property. *Carborundum Metals Co.*

AUGUST, 1958

215	236	257	278	299	320	341	362	383	404
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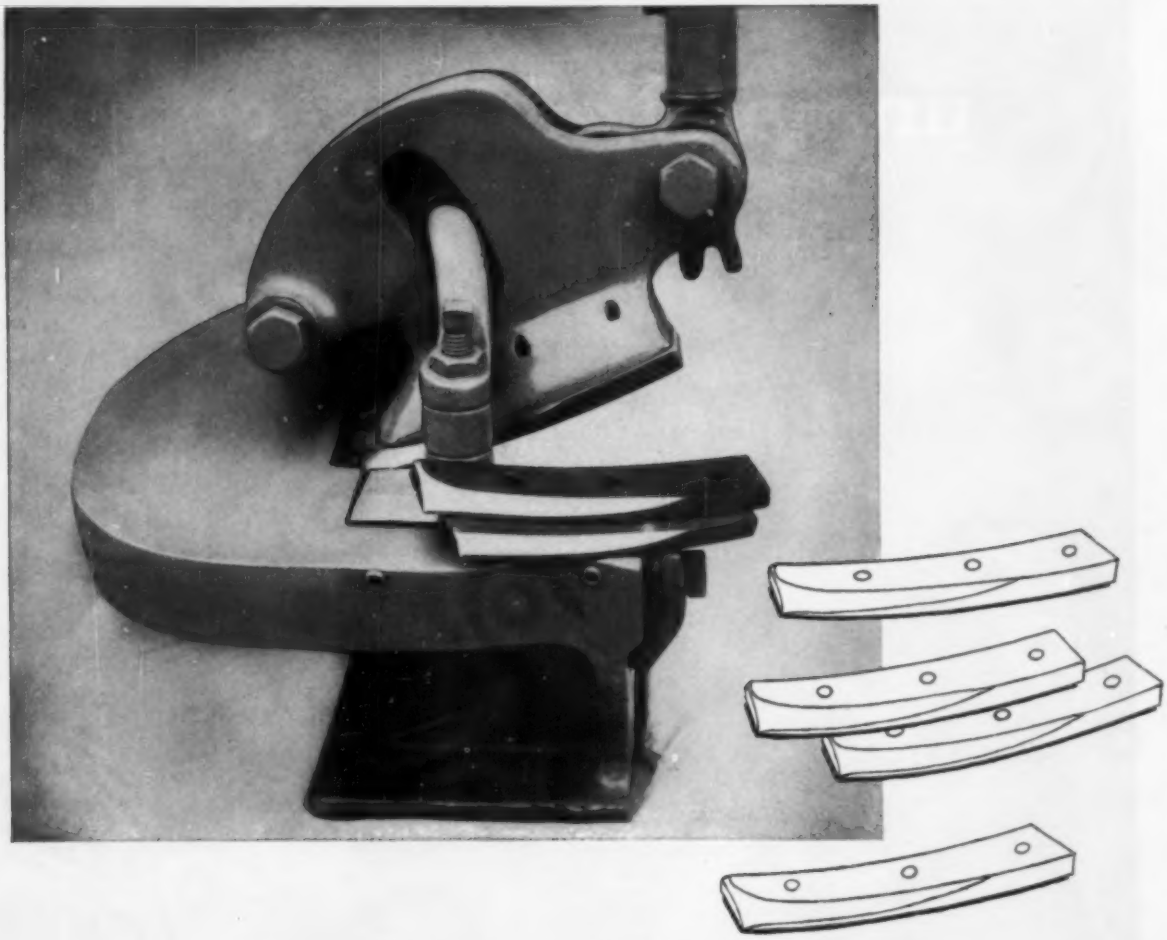
Postcard must be mailed prior to Nov. 1, 1958. Students should write direct to manufacturers.



Shear Manufacturer ups blade life 4 to 5 times . . .

with A-L HURON DIE STEEL

Write for Your
HURON BLUE SHEET

A compilation of facts on the handling and shop treatment of Huron. Includes complete information on forging, annealing, tempering, etc. and detailed laboratory data on physical characteristics. *Ask for your free copy.*

ADDRESS DEPT. MP-8

A Chicago bench shear manufacturer produced some test blades of A-L HURON die steel—heat treated to 61-62 Rockwell C.

Service life of the HURON blades proved to be four to five times that of the former blades. Resharpenings were reduced 75 to 80%! Because these new HURON blades held an exact rake and maintained a proper cutting arc, they easily sheared 3/16" mild steel or 10 gauge stainless.

HURON die steel was developed for use where high resistance to wear and abrasion is necessary, and where heavy pressure rather than sudden shock must be withstood. HURON has excellent non-deforming properties, and hardens to a great depth.

There is an A-L tool steel that will help solve your cutting, forming or blanking problem. Call our nearest office or distributor today about your requirements. ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.***

For nearest representative, consult Yellow Section of your telephone book.

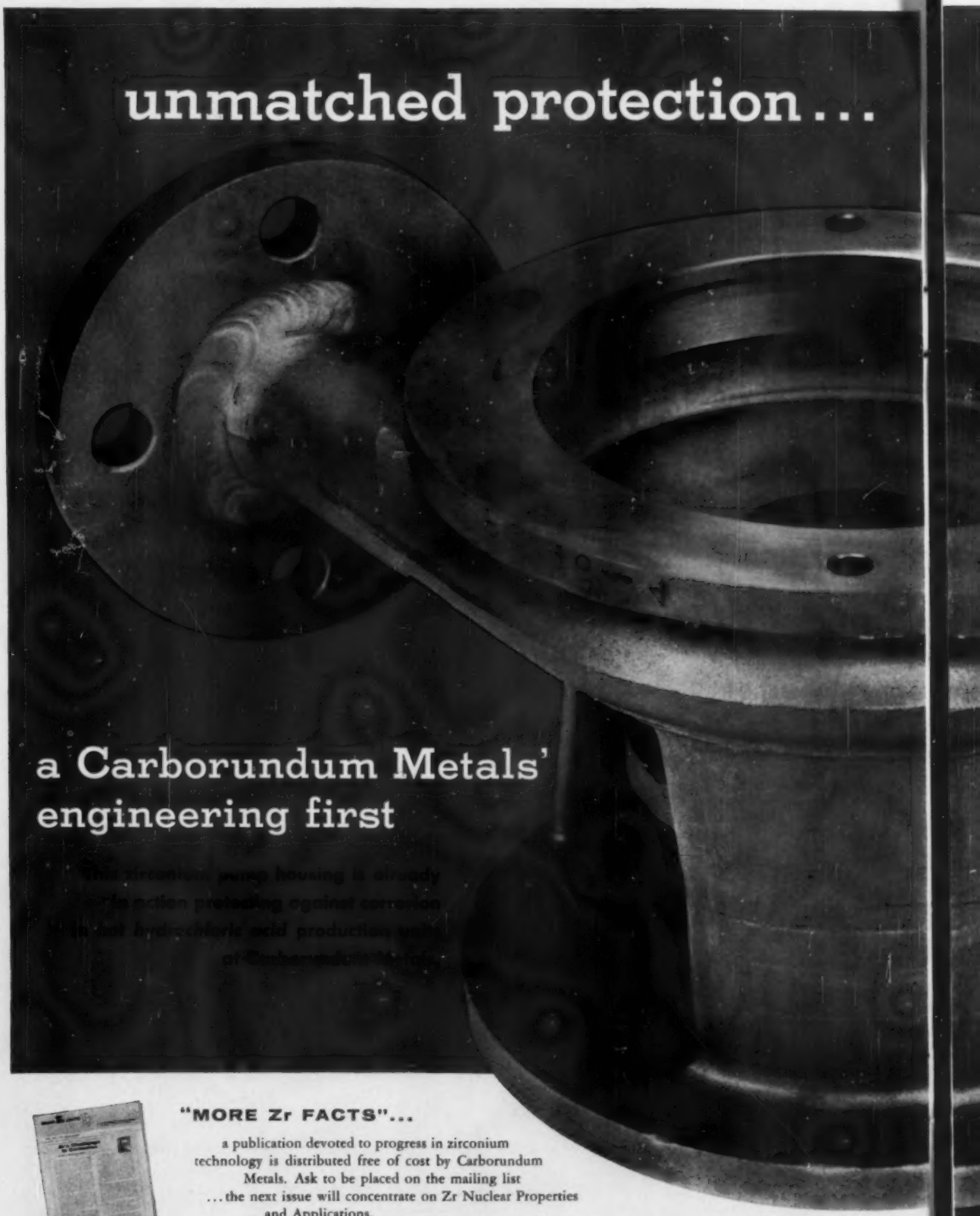
For complete MODERN Tooling, call

Allegheny Ludlum

WSW 6506

AL ® PINE TOOL STEELS SINCE 1854

unmatched protection...



a Carborundum Metals' engineering first

"MORE Zr FACTS"...

a publication devoted to progress in zirconium technology is distributed free of cost by Carborundum Metals. Ask to be placed on the mailing list ...the next issue will concentrate on Zr Nuclear Properties and Applications.

Zr pump casting

cast...welded and machined for long-term action!

Progress in zirconium fabrication techniques is evidenced in intricate cast-weld assemblies such as this impeller housing. Similar zirconium components are *immediately available* through Carborundum Metals for system designs where the versatile properties of this metal provide outstanding benefits:

FOR THE NUCLEAR INDUSTRY—low neutron cross-section for fuel cluster ends and other reactor components.

FOR THE CHEMICAL INDUSTRY—super corrosion resistance to attack by acids and caustics on basic components such as valves, pumps, heat exchangers, thermowells and reaction tanks.

Carborundum Metals' pioneer experience in zirconium production, its two completely modern and fully integrated producing facilities provide a ready and dependable source for every zirconium requirement... in commercial and nuclear grade sponge and ingot. Close working relations with highly qualified fabricators permit Carborundum Metals to provide definite quotes and assure on-specification delivery of welded or seamless zirconium tubing, zirconium sheet, strip, bar, rod and foil.

Write today **for latest price schedules and data sheets on all zirconium products. Address inquiries to Dept. 91-801.**

THE CARBORUNDUM METALS COMPANY, Akron, N.Y.
Division of THE CARBORUNDUM COMPANY

Production Pioneer of ZIRCONIUM

CARBORUNDUM

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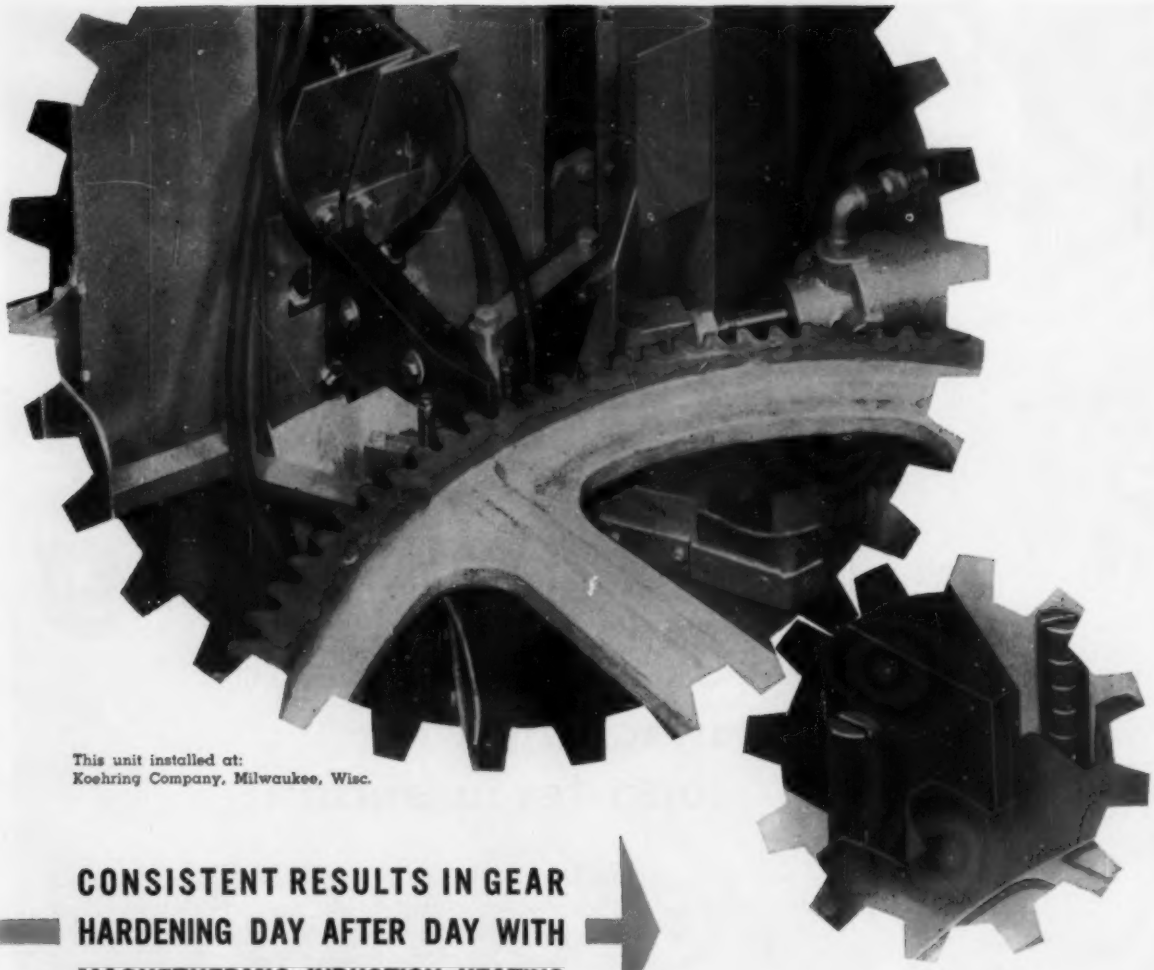
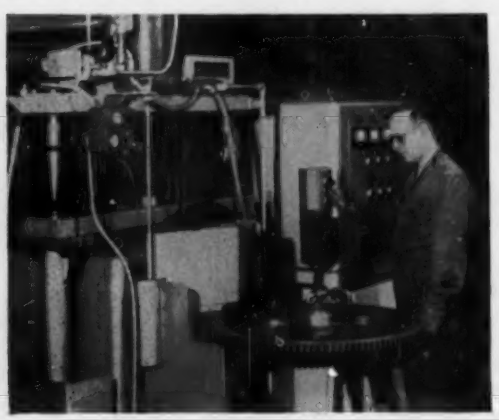


This unit installed at:
Koehring Company, Milwaukee, Wisc.

CONSISTENT RESULTS IN GEAR HARDENING DAY AFTER DAY WITH MAGNETHERMIC INDUCTION HEATING



Magnethermic tooth-by-tooth Gear Hardener produces a product superior to any gear produced by other heat treat methods. The secret—hardening the root as well as the contact surfaces. This method increases the tooth strength at little increase in gear cost.

In some cases, customers have been able to reduce gear size and cost because of added gear strength resulting from the Magnethermic hardening process.

The Magnethermic unit is easily integrated into production flow. The automation advantages of induction heating minimize the training of operating personnel. Users are able to get extremely consistent results from day to day.

MAGNETHERMIC®
CORPORATION
3990 SIMON RD. • YOUNGSTOWN 7, OHIO

Engineering Idea Leadership in Induction Heating
60 to 450,000 Cycles

AEC ENGINEERING GIVES *Better Service* ON TUBE HANGERS

ACCOLOY POINTERS to *Improved Performance* OF HIGH TEMPERATURE TOOLING

PROBLEM:

A leading Petro-Chemical company* needed a better alloy product—TUBE HANGERS that were DEPENDABLE. Maintenance down-time and costs must be reduced under increasingly severe plant operating conditions.

SOLUTION:

AECCo. applied its unique design background and proprietary casting technology in creating the component illustrated. The principle of self-equalizing load distribution (A), the balanced shear stress provided by large bushings (B), the contoured equi-stressed sections (C), and edges (D), were combined with special casting techniques in accordance with AECCo. "Standard Practice."

RESULTS:

Several months of rigorous service testing confirm that new PERFORMANCE standards have been achieved. Easier installation, drastically reduced maintenance, and more dependable operation result from AECCo. ENGINEERING.

MORAL:

Contact AECCo. for BETTER HIGH TEMPERATURE TOOLING.

ALLOY ENGINEERING & CASTING COMPANY

1700 W. Washington St. Champaign, Ill.
Tel: Fleetwood 6-2568

**Name available on request.*

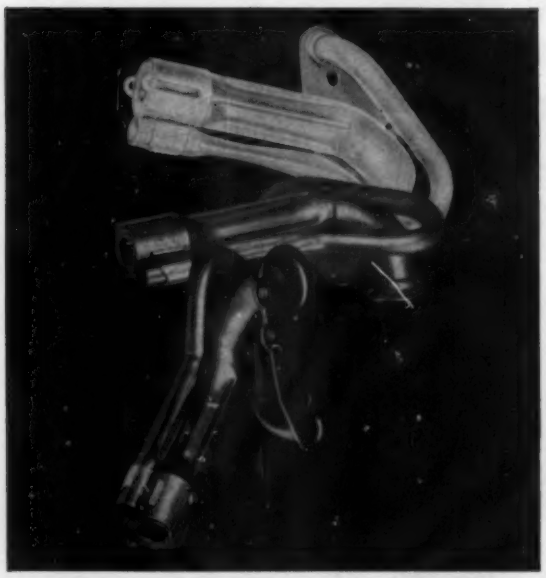
A "OVER AND UNDER" ASSEMBLY OF ADJACENT SECTIONS FOR SELF-EQUALIZING LOAD DISTRIBUTION.
B SHEAR STRESSES FROM SERVICE LOADS APPLIED TO LARGE BUSHINGS; BOLTS AND COLLARS USED ONLY FOR RETAINERS.
C ALL SECTIONS CONTOURED FOR EQUI-STRESS, (NO "WEAK LINKS" IN THIS CHAIN).
D SUPPORTING SURFACES BEADED FOR MINIMUM STRESS CONCENTRATION IN TUBES. ALL EDGES RADIUSED PER AECCo. "STANDARD PRACTICE".
PATENT PENDING

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

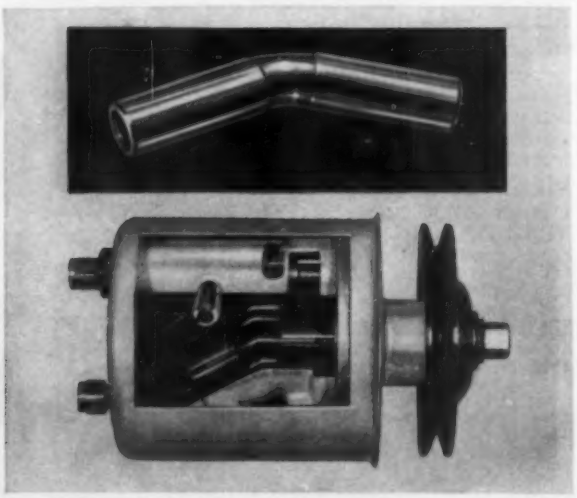
ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

...Flange it!
Flare it!
Bend it!
Expand it!

Republic ELECTRUNITE

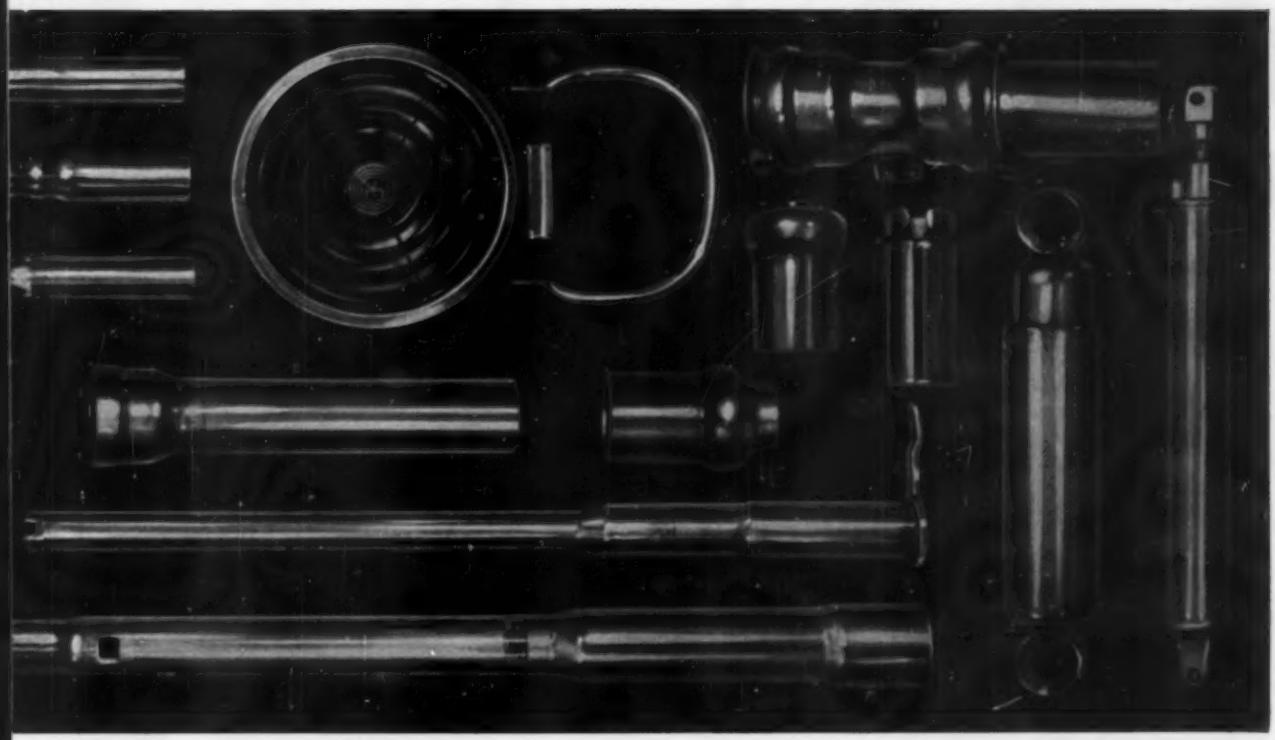


RANGE BURNER MANUFACTURER STEPS OUT with Republic ELECTRUNITE Mechanical Tubing. Harper-Wyman Company uses it in forming lightweight, easy-to-clean venturi burner tubes. The company subjects ELECTRUNITE to a hairpin bend of 1¼ diameter radius, then a four-way crimp, followed by punching, notching, and welding. Uniform, predictable ductility avoids stretch and collapse as tubing is severely bent and formed. Republic engineers will help you design ELECTRUNITE into your product to speed production, cut costs, and improve performance. Mail the coupon for facts. Or call your Republic representative.



WHEN IT'S MOVING . . . MAKE IT TUBING

Republic ELECTRUNITE meets all close tolerance requirements for new Thompson Products automotive pump. Close tolerance, uniformity, ductility, workability — four important performance requirements, all reasons why Republic ELECTRUNITE Mechanical Tubing is used in a new automotive hydraulic power pump assembly. This pump furnishes power for power steering featured by a nationally famous automobile manufacturer. Will-O-Hill Industries, Inc., Willoughby, Ohio, sub-contractor, manufacturers and specialists in close tolerance tubular stampings, cut ⅞-inch diameter ELECTRUNITE into units 2⅜ inches long. Each unit is rolled to form a slight groove in the center and bent to an angle of exactly 150°. Nine such pieces are used in each pump assembly. For additional information, send coupon or write today.



Mechanical Tubing

fabricates easily . . . economically . . . with uniformity

Quality makes the big difference!

Republic ELECTRUNITE® Mechanical Tubing is quality-controlled from ore to finished product; produced from highest quality flat-rolled open-hearth steel made in Republic's own mills; carefully inspected to Republic's rigid requirements. Republic Tubing is welded by the exclusive ELECTRUNITE process—a continuous electric weld method that unites the wall under pressure without the addition of foreign or extra metal. Tests prove the ELECTRUNITE weld is as strong or stronger than the original base metal.

Among other advantages, this process assures uniformity of wall thickness, strength, ductility, concentricity, diameter, and physical and mechanical properties. And as the world's largest producer of specialty welded tubing, Republic has the facilities, abilities, and equipment to tailor the tube to your end use. Republic also offers complete tube fabricating facilities.

Let Republic engineers help you select the most economical ELECTRUNITE Tubing to meet your severe processing needs. Call your Republic representative or write today.

REPUBLIC STEEL

World's Widest Range of Standard Steels and Steel Products

REPUBLIC STEEL CORPORATION
STEEL AND TUBES DIVISION
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Please send the following information:
- ☐ Republic ELECTRUNITE Mechanical Tubing
- ☐ Fabricating Facilities
- ☐ Please have a Republic Engineer call

Name_____ Title_____
Firm_____
Address_____
City_____ Zone_____ State_____

25 Years of Troublefree Temperature Control!

Zone Temperatures in both hardening and tempering sections of this American Gas continuous furnace at Holo-Krome Screw Corporation, Hartford, Conn., are maintained within tolerances of ±10°F by 6 Foxboro Type 4000 Potentiometers (on panel at left). Multi-Record Dynalog* Recorder (center of panel) logs precise temperatures in critical discharge zones.

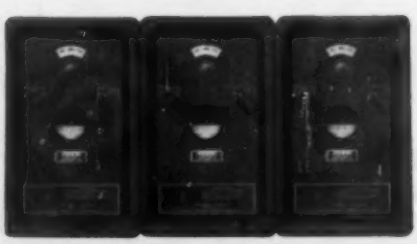
*Reg. U. S. Pat. Off.

. . . so Holo-Krome again selects Foxboro Type 4000 Potentiometers

Selecting dependable temperature control was no problem when Holo-Krome Screw Corporation recently transferred batch hardening and tempering operations to its new continuous furnace. Foxboro Type 4000 Potentiometers had provided smooth, precise control on batch furnaces . . . requiring only routine preventive maintenance and one major part replacement in 25 years! So Type 4000 got the new assignment — and once again are providing the accuracy and dependability that the company's high quality standards demand.

This is a typical example of thousands of successful Type 4000 applications on heating, annealing, melting, and creep-test furnaces, pickling tanks, and similar installations. They maintain accuracy to ¼ of 1% of scale, sensitivity to a fraction of a degree, give years of troublefree service. Let them help you to get a better quality product and higher productivity. Write for Bulletin 16-10.

The Foxboro Company, 528 Neponset Ave., Foxboro, Mass., U. S. A.



Only one motor is needed to drive up to 5 Type 4000 Potentiometer Controllers . . . real economy without the slightest sacrifice of accuracy or efficiency.

FOXBORO
REG. U.S. PAT OFF.

CONTROLS FOR THE METAL INDUSTRIES

Tool Steel Topics

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

BTR blanking die trims costs of power mower parts

This is part of a blanking die, made of BTR tool steel, which was manufactured recently by American Machine & Tool Co., Minneapolis, for use in forming a sheet-steel foot rest for a power mower.

"We first discussed the job with Paper Calmenson and Company, Bethlehem's local tool steel distributor," said one of American's engineers. "Their recommendation was BTR . . . because it's safe-hardening, tough, and has plenty of resistance to wear. It was a good choice. The die performed well, and our costs were kept low."

BTR (Bethlehem Tool Room) is our general-purpose, manganese-chromium-tungsten grade of oil-hardening tool steel. Time after time it gives long service, and trims down those production costs. That's why manufacturers keep coming back for more, and for a wide range of applications.

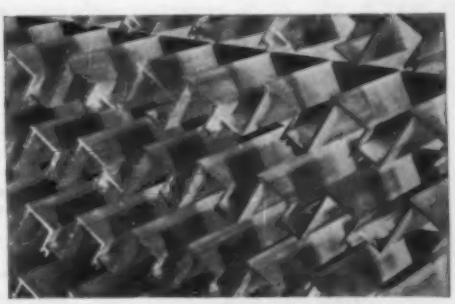
If you haven't yet experienced the advantages of BTR in your shop, why not order enough for a trial run from your Bethlehem tool steel distributor? It's one of the wisest moves you can make. Give him a call right now, while you have it in mind.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Letter Stamping Should Be Avoided

Many tools are stamped with number or letter die-stamps for identity, or to incorporate such information as size. But stamped impressions introduce sharp notches which serve to concentrate stresses both in the hardening operations and in service, and cause many service failures which would not have occurred in the absence of stamping. It is impossible to predict which stamped characters will cause trouble due to cracking. Often identical stamped tools develop little or no cracking through stamped characters, while duplicate lots may show a high percentage of such cracking.

Avoiding the use of stamped characters in tools and dies will be found to improve the service life, if a statistically large group of tools is studied. This result does not always occur on single tools, nor on a small number of tools. Yet there is no doubt that the elimination of stamping benefits tool life. In the light of present-day knowledge of the effects of stress concentration, it is intolerable that such stress-raisers as stamp marks be put on tools and dies intentionally. Stamping of characters can be avoided by resorting to the use of paint, labels, etching, or "electric pencil" to place the necessary information on the tool surfaces.



PATTERN IN EXTRUSIONS. These long metal extrusions, made by American Aluminum Extruders, Miami, were formed with a die of Cromo-WV. This grade, with its .30 pct vanadium content, is a modification of Cromo-W, our general purpose hot-work steel. Cromo-WV is an excellent tool steel grade for extrusion work because it has a well-balanced combination of properties: wear resistance, red hardness, and shock resistance, plus resistance to heat-checking.

WILSON "ROCKWELL"

HARDNESS TESTERS • *WORLD'S STANDARD OF ACCURACY*

ACCO for Better Values

Equipment for *EVERY Hardness Testing Requirement*

WILSON "ROCKWELL" HARDNESS TESTERS ... ACCURATE AS A PRECISION BALANCE

No matter what your hardness testing requirements are, there's a WILSON "ROCKWELL" instrument to do the job. Choose from this complete selection of hardness testers:

"ROCKWELL"—for most hardness testing functions.

Superficial—for extremely shallow indentations.

Twintester—combines functions of "ROCKWELL" and "ROCKWELL" Superficial testers.

Semi-Automatic (*manual feed*) *and Fully Automatic*—for automatically classifying tested pieces as CORRECT, TOO HARD, or TOO SOFT—at test rates up to 1000 pieces per hour.

Special Machines—for testing large objects, obtaining internal readings, and other unusual applications.

ALL WILSON "ROCKWELL" hardness testers provide these advantages:

Accurate performance—precision built, with exact calibration, for consistently correct results.

Long life—durable as a machine tool.

Easy operation—even an unskilled operator can get perfect readings. All controls conveniently grouped.

Easy maintenance—interchangeable mechanisms, with spindles mounted on oil-less bearings.

DIAMOND "BRALE" PENETRATORS ... perfect testing every time

A perfect diamond penetrator is essential to accurate hardness testing. Since one point of hardness on the "ROCKWELL" scale represents only 80 millionths of an inch penetration—only 40 millionths on a Superficial tester—the slightest imperfection will cause a false reading.

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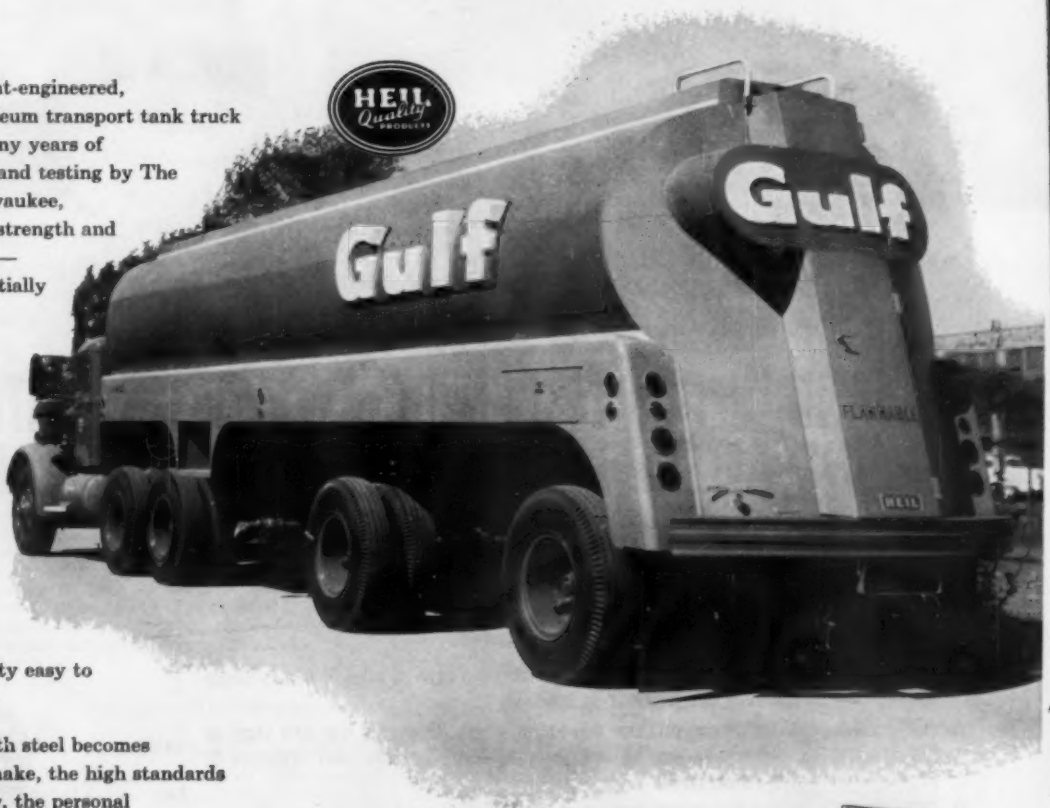

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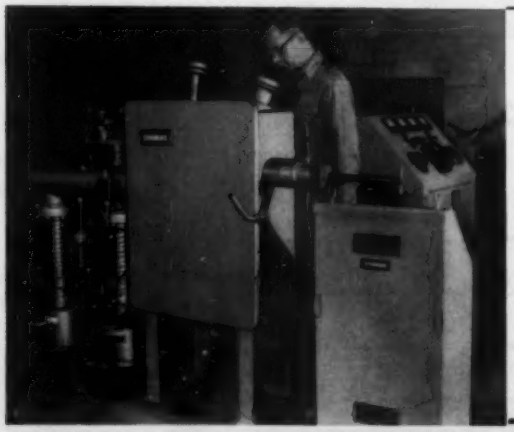

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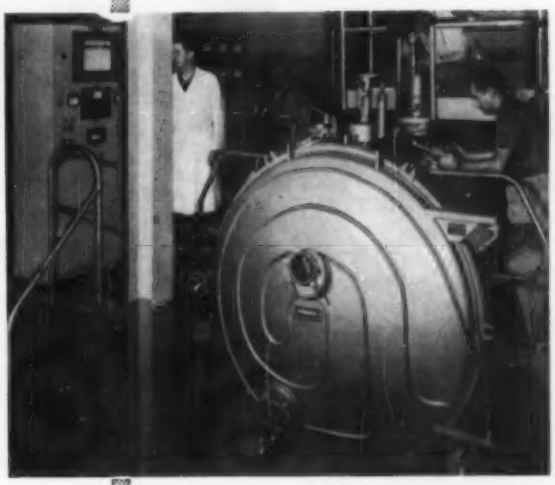

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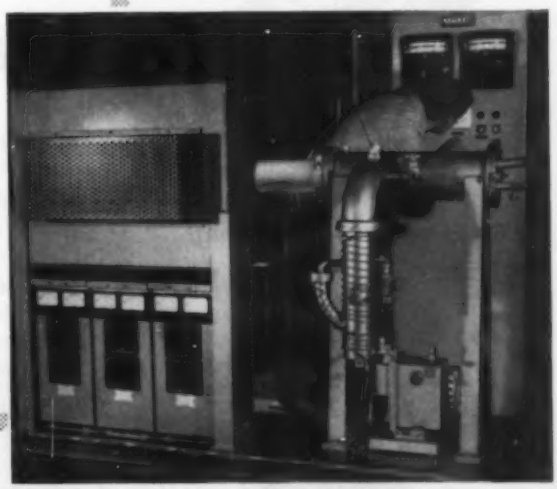

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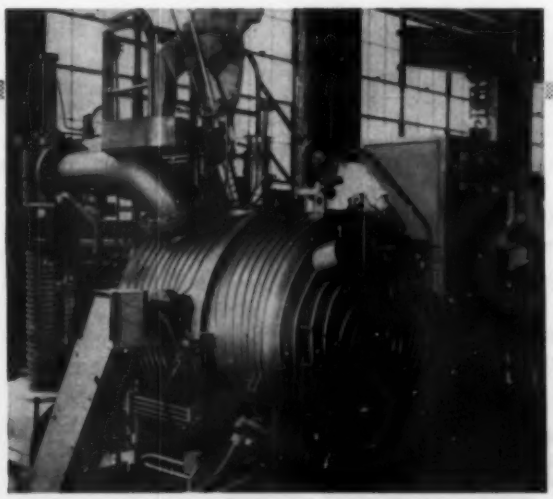

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Metal Progress
Volume 74, No. 2 August 1958

Critical Points

Are Scientists People?

BACK IN THE THIRTIES, the popular concept of a scientist was that of a little man with thick glasses wearing a food-stained white coat. He had a mad gleam in his eye, and was usually crouched over a laboratory bench as he poured a bubbling concoction from one test tube into another. The famous motion picture "Frankenstein" along with some rather ridiculous advertising copy has contributed to this fictitious impression.

With the atomic bombs and sputniks of recent years, the picture has changed somewhat, though the situation has hardly improved. Nowadays, the common idea is that a scientist sits at a desk surrounded by complex electronic computers while he doodles away at some involved equations which may or may not be useful. His only interest is his work; he neglects all else – family, religion, hobbies, friends–in pursuit of his eccentric dreams. Confined, poorly paid, driven by incomprehensible desires – who would want to be a scientist?

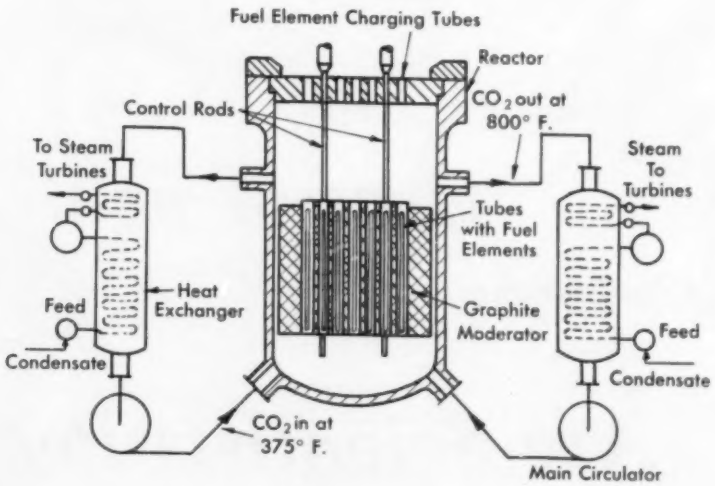
Of course, neither idea is even remotely within reason. It is comforting to know that a recent survey made by the Du Pont Co. of its technically trained people engaged in research shows that the average scientist is as active in every other human endeavor as he is in science. This is logical – after all, the scientist's basic trait is curiosity. He wants to learn not only about his own field but about those around him, about their work and other activities – in short, everything that goes on in this great world is of interest to him.

For example, the survey shows he likes sports. Of the more than 1000 scientists investigated, 700 engaged in 42 different sports. Golf is the most popular, with bowling second. Tennis is

Theory Versus Practice

A BEAUTIFUL EXAMPLE of Admiral Rickover's statement in May *Metal Progress* (p. 66) calling attention to the vast difference between a glowing new concept for an atomic reactor and the mass of grubby work before it can become a reality, is the two drawings herewith. The schematic below illustrates the "concept" of a graphite-moderated, gas-cooled system to generate steam for a central electric station. Simple in the extreme! Merely a pressure vessel flanked by heat interchangers; recirculating CO_2 gas transfers heat out of the reactor and generates steam which (free from radioactivity) goes to a turbogenerator.

On the opposite page behold a cut-away drawing of the Hinkley Point Nuclear Power Station under construction for Great Britain's Central Electricity Generating Board by English Electric, Babcock & Wilcox and Taylor Woodrow. Same simple concept. E.E.T



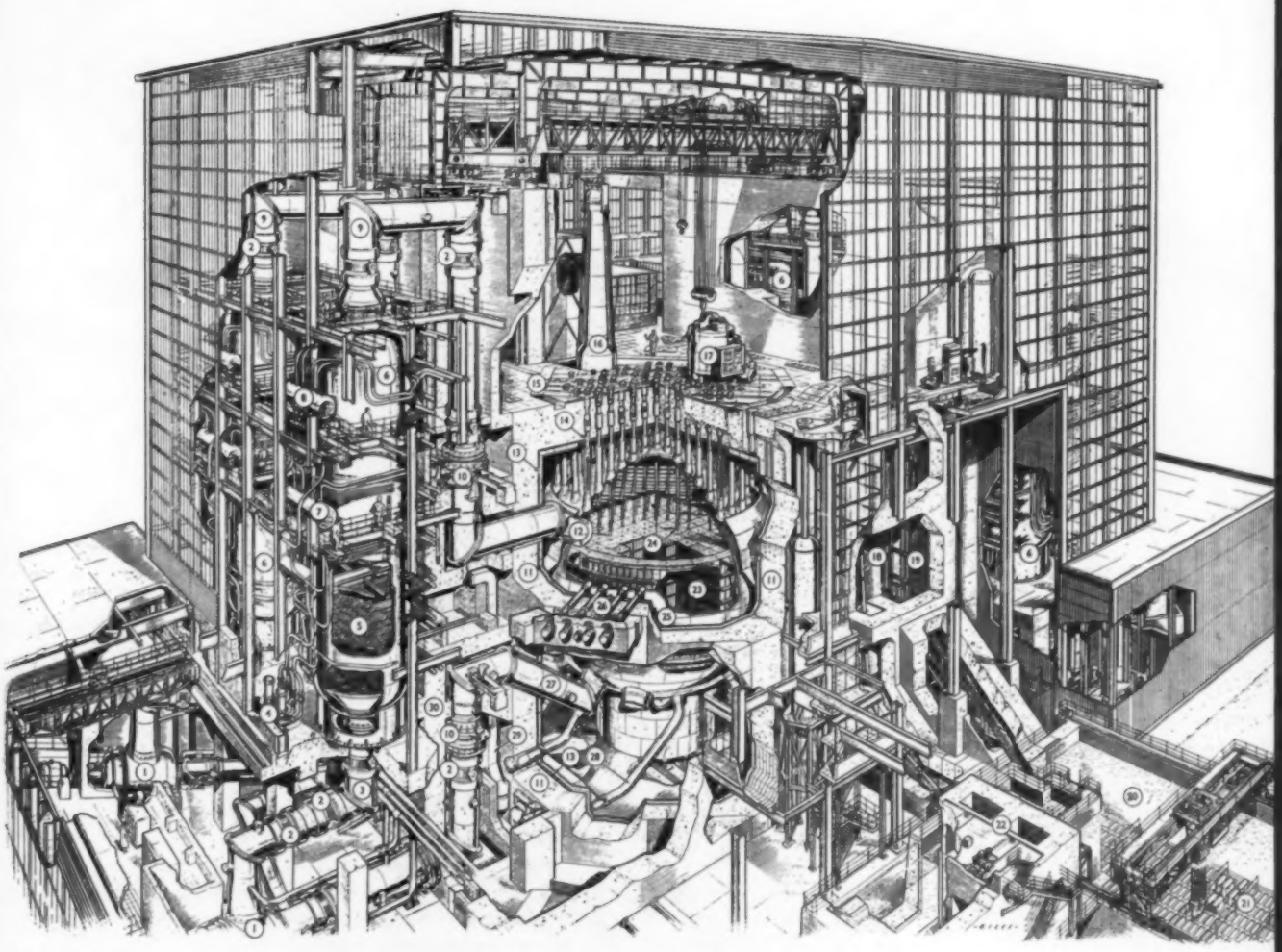
third, while fishing, softball, swimming, hunting, basketball, and sailing are also of great interest.

Is the scientist a gloomy woman-hater? Well, 88% are married as opposed to 85% in the general population. Furthermore, his family consists of two or more children. The figure for offspring might be considered rather odd until we learn that the average family is 1½ children! (Buying Christmas gifts must be quite a problem for the average family.) Three of Du Pont's scientists are obviously interested in more than test tubes; they have seven kids apiece.

Also contrary to the general impression is the finding that scientists are religious. Some, 23%, to be precise, are Sunday school teachers or supervisors, 18% are church officers, 16% belong to men's clubs, another 16% to church committees, 9% sing in the choir, and 5% aid youth groups. Some record for the "godless" scientist!

Are scientists immersed in their work to the exclusion of everything else? The study does show that they are definitely interested in whatever they happen to be doing at the time. This can include anything. Among favored hobbies are gardening, woodworking, photography, bridge, dancing and organized reading. While it might be said that "organized reading" is the sort of hobby that only a scientist would dream up, reading is still fairly common despite television's inroads.

We find that scientists indulge in quite a variety of other hobbies, too. They mention in returned questionnaires such interests as cooking, collecting Civil War items, knitting, bird watching, archeology field work, painting, sewing, telescope building, writing, rocket design, music theory, sports cars, antique refinishing, electronics, hi-fi, chess, and linguistics. No



apologies are made for the knitters and bird watchers; truck drivers have been known to collect streetcar transfers and matchbook covers.

Many different societies interest the research worker, as well. He participates in political groups, dramatic clubs, military organizations, social sets, and other miscellaneous combines devoted to such things as photography, orchids, stamps, natural history, and the U.N.

The survey goes on to show that there is practically nothing that exists which doesn't attract the attention of at least one scientist. A number are interested in music to the extent of playing in their own bands, others do Y.M.C.A. work, while 21% are active in fraternal organizations. All in all, a surprising record to place in front of anyone who regards a scientist as an ivory-tower, head-in-the-clouds theorist.

Let's face it! You scientists who read this know very well that you are not the gregarious, back-slapping type alleged to be prevalent in some other professions, but neither do you shrink from the world. You drink beer, yell when Musial smacks one over the wall, get mad when some meathead swipes your parking spot — in short, you are human. Perhaps the main differences lie in your creativity and curiosity. Both enable you to take an active interest in any subject. Basically, you are not a breed apart but are in this world along with the rest of us.

Well, why not say so? Let your neighbors know that you're in the same boat they are, and are, furthermore, in a position to make it move a little faster. Our great need today is for more young people to enter science. You can help, by example, in the development of a wholesome popular attitude toward scientists and science. Are you doing this? C.R.W.

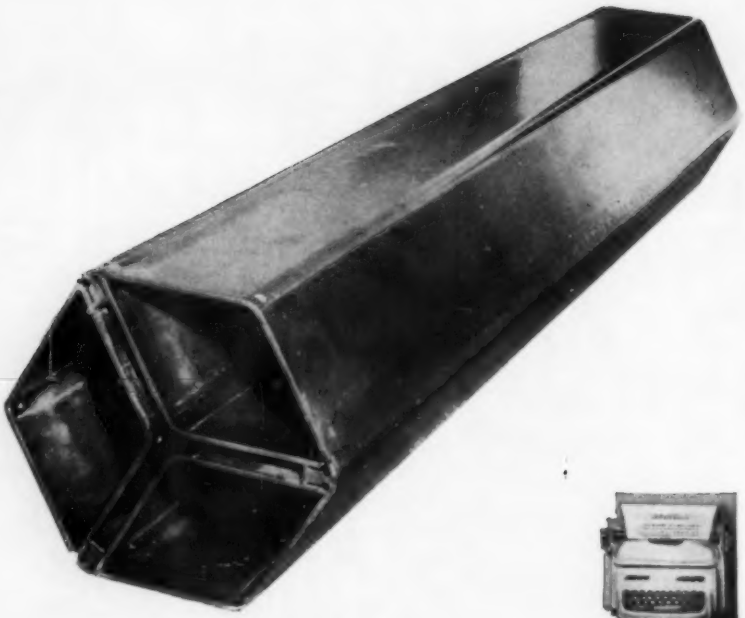


Fig. 1 – This 4-Ft. Tube Structure (Rhombus Assembly) Is Produced From Zircaloy Plates Which Are Formed and Welded Into Individual Rhombuses. These are welded to spacers to give the finished assembly.

Staff Report

A Lesson in Fabricating Nuclear Parts

Fabricated reactor components are produced from zirconium alloys and hafnium using metalworking techniques developed for precision and to avoid contamination. Welding is in a dry box, heat treating is in a vacuum; forming is done hot. Surface treatment and testing methods are special, too. Here is a look at an area of metal fabrication that is bound to grow. (T11, G-general, J-general, K-general; Zr, Hf)

Fig. 2 – Lower Portion of This Reactor Control Rod Is Fabricated From Hafnium, Upper Part Is Zircaloy. The joint is made by butt welding. Wear pads are hot coined on the lower part of the hafnium section

COVERING the advanced needs of industry and defense is today's most difficult technological job. In 1956, Superior Tube Co. formally established its Nuclear Products Div. in Phoenixville, Pa., to fabricate hard-to-handle reactive metals into various types of components needed for atomic energy. Recently the Editor of *Metal Progress* visited Superior's nuclear division. Its director, J. B. Giacobbe, revealed the special techniques in forming, welding, heat treating, finishing and testing which are used to fabricate highly precise parts (of unusual configuration) from zirconium alloys and hafnium.

Two reactor components being made by Superior for Knolls Atomic Power Laboratory are shown in the photos above: Figure 1 is a 4-ft. tube structure (rhombus assembly) for use inside a reactor core produced entirely from zirconium alloy, Zircaloy-2. Figure 2 is a reactor control rod fabricated from hafnium and Zircaloy-2. While this report will deal with specific procedures used with these two components, the operations cover many metalworking problems which would be encountered in fabricating parts from these reactive metals.

Forming Zircaloy and Hafnium

The tube structure assembly (Fig. 1) is made by welding three rhombus assemblies to three spacers. The first operation in fabrication is forming Zircaloy plates into the rhombus shape.

Several factors are involved in bending cold rolled zirconium alloy plates to an included angle of nominal 120° F. and a bend radius of 3/32 in. Quality of material is a big factor, particularly with respect to surface defects and contamination. X-ray, dye penetration inspection and metallographic examination are used to detect harmful surface and subsurface defects. As a further criterion of quality, a bend test at room temperature to a 90° included angle, with a 5 T radius, should reveal no cracking at the point of maximum deformation. Metal free of surface defects and contamination, and vacuum annealed to an average hardness of Rockwell B-95 for Zircaloy-2 (B-90 for Zircaloy-3) will generally pass the bend test.

The Zircaloys and hafnium have low ductility below 900° F., particularly in the direction parallel to rolling. Bending of Zircaloy plates without formation of surface cracks can be done at temperatures in the range 900 to 1000° F. Too low temperature for forming causes cracks. Closely associated with the right temperature for forming is the need for fast heating to reduce chances for harmful surface contamination to a minimum. Rapid heating to 950° F., in a molten potassium-lithium-sodium carbonate salt, is recommended.

Uniformity of die temperature also has an important bearing on variation of angle in the as-formed plates. Heating the bending die in the temperature range 800 to 900° F. prevents rapid undercooling of the Zircaloy in the area of contact and assures consistent bending results. By proper insulation of the die to prevent local heat losses, the temperature over the entire length can be held to ±25° F.

Flatness of the Zircaloy plate and hafnium blades is an important factor in fabricating the rhombus assemblies and control rods. A method of annealing was devised which produces a flatness of 0.001 to 0.0015 in. per ft. In fabrication of the control rod the hafnium blade is placed between two flat, low-carbon, steel plates 1 × 5 × 48 in. long. The sandwich is clamped with cross bars and heavy steel bolts every 12 in. to give a uniform pressure over the entire length of the blade. The assembly is then heated in a vacuum (less than 1 micron) at 1300° F. and held for 1 hr. for each inch of fixture thickness.

A similar method is used for Zircaloy plates. The as-rolled material is placed between two heavy (1½ in. thick) machined steel plates and tightly clamped with bolts at 6-in. intervals. Thin (0.035-in.) sheets of low-carbon steel between the Zircaloy plates prevent sticking. Roller leveling used at first was abandoned in favor of this method.

Forming Wear Pads

To form the wear pads in the lower end of the control rod, a hot coining operation is used. Wear pads having satisfactory dimensional control were obtained by heating the lower 6 in. of the control rod in the molten salt bath for 2 min., at 1700° F. The work is transferred rapidly to the heated die (950° F.) to avoid excessive temperature drop. The temperature of the metal just prior to forming is approximately 1300° F. A load of 50 tons is adequate. No embrittlement was detected as a result of this operation.

Welding

Zircaloy and hafnium are easily contaminated by absorption of oxygen and nitrogen. A "dry box" must be used for inert arc welding. This is a sealed chamber which resembles an iron lung (Fig. 3). It has a vacuum system which will pump down the atmosphere to 1 micron in about 20 min., with a leak rate not exceeding 5 microns

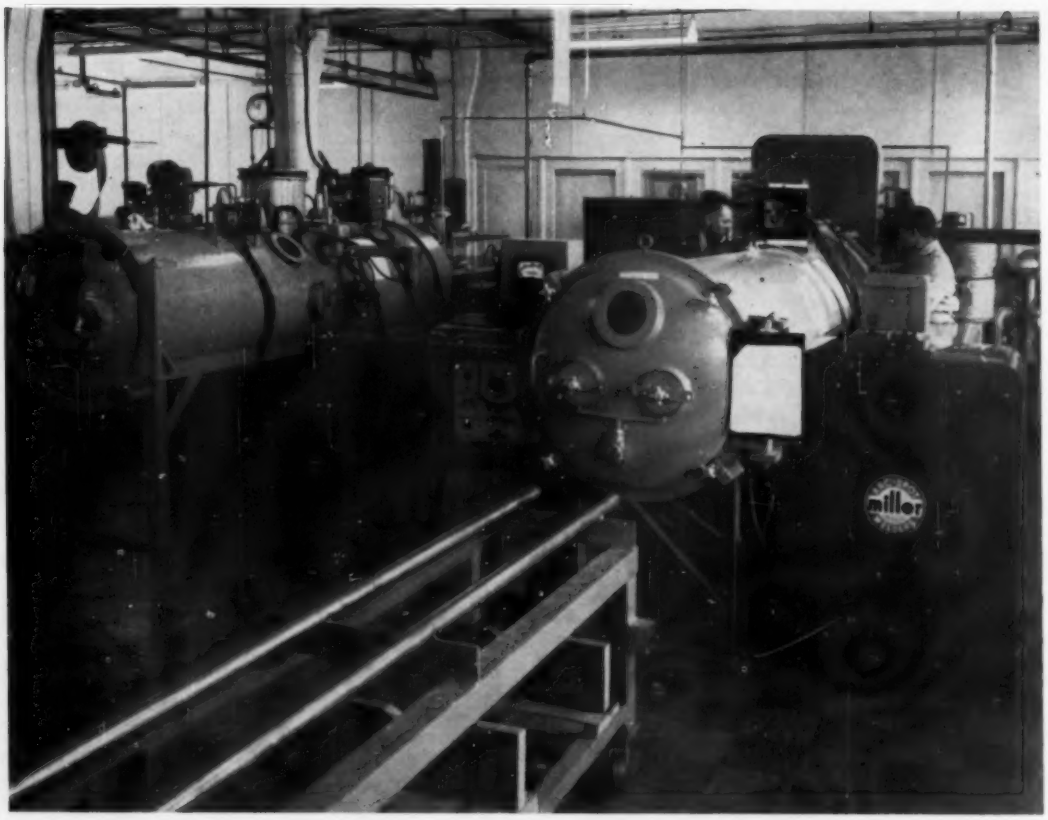


Fig. 3 – Zirconium Alloys and Hafnium Are Welded in a Large Dry Box Which Resembles an Iron Lung. The vacuum system will pump down the atmosphere to 1 micron in about 20 min. The chamber is back-filled with argon or helium for welding

per hr. during the first 5 min. before each welding operation. The chamber is back-filled with argon or helium. It is generally pumped down and back-filled one to three times and the atmosphere checked for purity before welding is started.

Welding boxes are equipped with automatic arc voltage control in the range 14 to 25 v. Thoriated (2%) tungsten electrodes, ⅛ in. to ¼ in. in diameter, are used for welding Zircaloy and hafnium plates. Welding current up to 500 amp. is supplied by standard welders. Tack welds are first spaced along the joint to hold the structure as assembled and to prevent distortion during welding. Then the seam is fusion welded its full length. With the arc struck, the tungsten welding electrode automatically follows the joint as the weldment is carried along the track.

One example of a control rod might consist of three hafnium blades welded into symmetric Y-shape with a Zircaloy hub or adapter welded to the top section. Satisfactory penetration of hafnium with a small amount of undercutting was obtained with a single continuous pass on each side of the blade section at the common junction. The photograph in Fig. 4 shows the maximum amount of undercutting observed in the section. Generally, it is less than 0.020 in. and can be blended smoothly into the contour of the blade section. These conditions are achieved with a welding current of about 190 amp. at 16 v. and a travel of 8 in. per min.

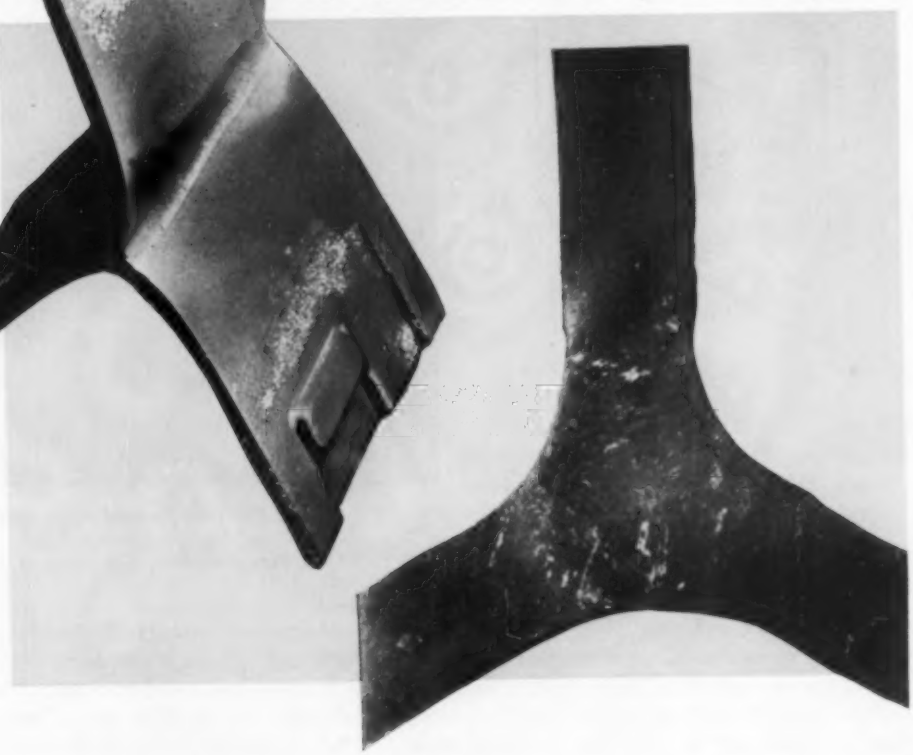
The hafnium blade weldment shows good ductility. To test this, an annealed specimen was pressed until the first visual evidence of weld failure occurred which allowed two blades to be deformed from 120° included angle to nearly 180° as illustrated in Fig. 5.

Butt Welding Hafnium to Zircaloy

Initially, some difficulty was experienced in forming this joint without excessive undercutting on the Zircaloy side. This is undoubtedly due to the relatively large difference in melting point of the two materials, which for a given welding cur-

Fig. 5 (Left) – Crush Test Made on Bottom Part of Control Rod Section Illustrates the Ductility of Weld Metal in Hafnium Blade Section. The part was deformed from 120° included angle to nearly 180° before first cracks appeared

Fig. 4 – This Section, Taken From Welded Hafnium Control Rod, Shows Maximum Undercutting Which Was Experienced



rent would allow a greater penetration, and thus more undercutting on the Zircaloy side.

To overcome this condition, a strip of Zircaloy filler, 0.035 in. thick, was added to the weld preparation. By welding about 1/16 in. off center on the hafnium side, sound welds were obtained with little or no undercutting. After welding, the excess filler is removed by machining. In welding the hub, copper back-up was used to control penetration and establish more uniform welding conditions.

Zirconium Welding

The method of producing a rhombus for the assembly consists of joining, by welding, two formed "V" plates (120° included angle) about 44 in. long and 0.180 in. thick. Development work was carried out by Superior to devise a weld preparation which would permit 100% penetration without melting or rounding off the rhombus edges and without excessive weld undercutting (depression in the weld metal below normal surface of the rhombus). In all, eight different preparations and a total of 90 different welding conditions were studied.

The weld preparation method illustrated in Fig. 6 gave the best evidence of providing the necessary conditions to achieve a completely satisfactory weld. With the Zircaloy back-up strip, it was possible to increase the welding current to 375 amp. without melting away the rhombus edge. At the same time, the height of the lip could be reduced and still provide the filler to minimize undercutting. Tests showed reinforcement well centered at the root of the joint; more than 30 specimens showed complete fusion and no undercutting. Most consistent results were obtained with a lip height of 0.060 in. and the top of the Zircaloy back-up 0.020 in. below the top of the lip.

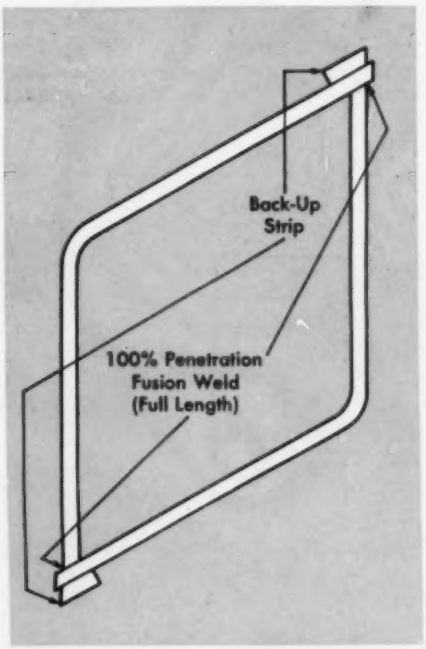


Fig. 6 – Diagram Shows Back-Up Strip Used for Rhombus Weldment

Fig. 7 – The Tinamel Steel Mandrel Is Inserted Into the Zircaloy Rhombus Prior to Size Annealing in Vacuum at 1450° F.

An important observation made in this development work was that intimate contact between the work and weld chills is essential to uniformity of results. Gaps in excess of 0.005 in. appear to disturb the heat balance along the weld sufficiently to produce irregularities in penetration and undercutting. For this reason, all chill bars are precision ground to insure intimate contact with the work.

Welding the rhombus parts, using the fixtures devised by Superior, is almost automatic after the arc has been properly established within the starting area, 2 in. from either end of the 44-in. length. Fully corrosion resistant welds showing 100% penetration, with controlled root reinforcement and virtually no surface undercutting, are produced with a welding current of 375 amp. at 15 v. and an electrode travel of 4 in. per min.

Uniformity of weldment is a function of the precision achieved in preparation and assembly of plates and components. Particularly important is the intimacy of contact between all adjoining surfaces. A gap of 0.005 in. maximum at all Zircaloy interfaces and 0.002 in. maximum between copper chills and Zircaloy is recommended.

The final rhombus assemblies are produced by joining three rhombuses, produced as described above, to three rhombus spacers. Optimum welding conditions were achieved with a rotation of 30° and 180 amp. and 16 v. using ⅛-in. electrode offset and travel of 6 in. per min.

As with the rhombus parts, the gap between adjoining surfaces must be held to a minimum in order to obtain a weldment having a high degree of uniformity. In the tube structure, this is accomplished by machining the rhombus assembly in the area adjacent to the machined rhombus spacer. A maximum gap width of 0.005 in. (which is considered necessary for good welding) can be maintained by this procedure.

Vacuum Annealing

Vacuum annealing at a pressure of less than 1 micron enhances the corrosion resistance of Zircaloy and hafnium and improves weld ductility. Hanging components vertically during treatment prevents any measurable amount of distortion. A full anneal for hafnium requires 1750° F. For Zircaloy-2, 1450° is adequate. However, the composite Zircaloy-hafnium sections in the control rod were annealed at 1450° F. with satisfactory results.

A vacuum sizing technique is used to expand the rhombus sections from the as-welded size to

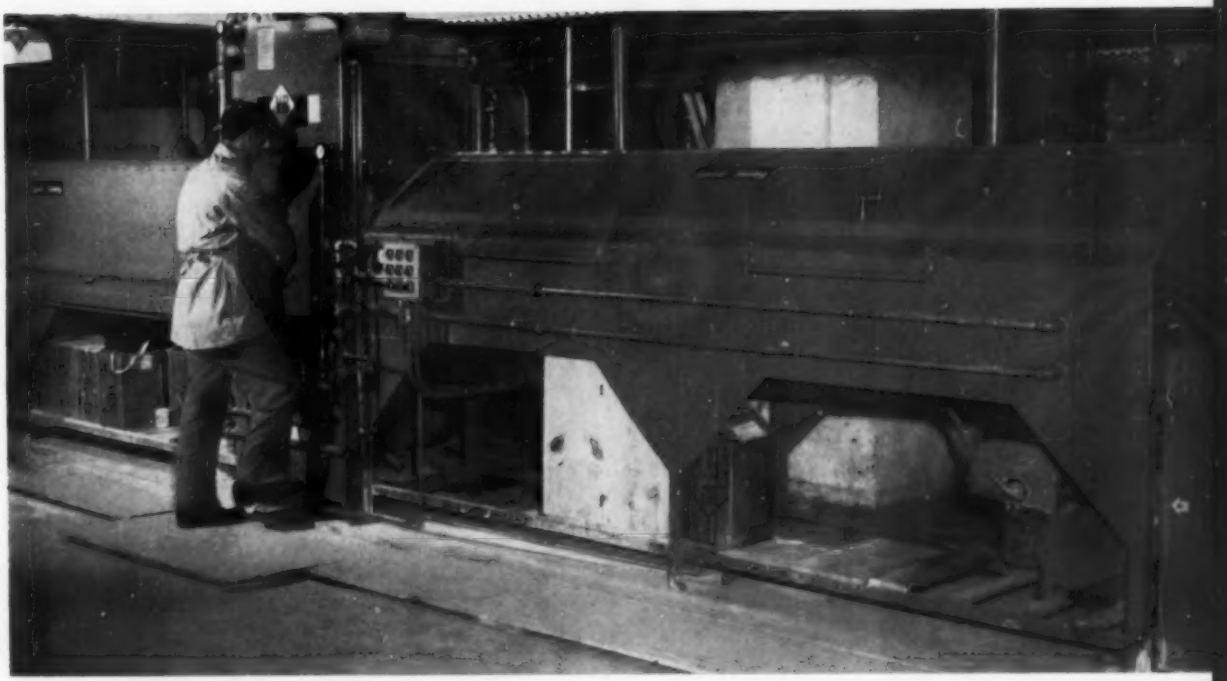


Fig. 8 – Blasting Cabinet Uses 200-Grit Abrasive in Water to Remove Oxide Films Resulting From Heat Treating, Welding, and Hot Forming. Parts travel under spray nozzle at a uniform rate

the required minimum free path. The method uses a Tinamel (low-carbon enameling steel) mandrel inserted in the rhombus. The assembly is heated at 1450° F. while suspended vertically in the vacuum furnace. Since the expansion of steel is about twice that of Zircaloy, mandrels of increasing size in the rhombus would with each anneal bring about an increase in the minimum free path. Several tests were made to determine the rate of increase in rhombus dimensions after each anneal. After production got under way, it was found that by welding assemblies closer to final size, two sizing anneals were all that was required. Figure 7 shows the mandrel being placed into the rhombus to get it ready for annealing.

Vacuum annealing of the rhombus parts with Tinamel mandrels is carried out in a stainless steel retort – about 20 in. in inside diameter and 60 in. inside depth. It is attached to a vacuum system capable of maintaining a pressure of 1 micron or less during the heating and cooling cycle. A 50-kw. pit-type electric furnace is used for heating.

Vacuum annealing of the tube structure after welding without removal from the fixture serves the dual purpose of improving weld ductility and giving final sizing required by weld shrinkage.

Machining

Zirconium alloys have a high rate of work hardening and tend to gall and build up on the cutting tool. (In this respect, they are not unlike aluminum or austenitic stainless steels.) They are pyrophoric and must be handled with care to avoid fires. Their abrasiveness leads to a high rate of tool wear.

Cutters for machining zirconium should be designed with high rake and clearance angles to produce a thin chip with a minimum of chip distortion. A rake angle of 15°, with a clearance angle of 6 to 10°, seems to give best results. On the other hand, work hardening characteristics of these alloys require that the depth of cut be such that the re-entry of the cutting tool is below the work hardened layer of metal. This should be determined empirically for the work being machined; the setup should reflect the best combination of speed, feed, coolant and cutting tool condition.

Carbide tools, ground with a fine, smooth cutting face and operated with an ample flow of water soluble coolant, perform satisfactorily. Machining can be done without coolant, except for the danger of starting fires. Turnings or chips may start to burn if machining generates suffi-

Fig. 9 – Vapor Degreasing, Pickling and Rinsing Is Done Vertically in Tanks 12 Ft. Deep. A high-speed hoist gets parts in and out of tanks as fast as possible

cient high temperature in them. Once a fire has started, it is difficult to extinguish. Where quantities are small and isolated, ignited material should be allowed to burn out. Dry sand or special types of fire extinguishers should be used when it is necessary to put out a zirconium fire. Common extinguishing agents, such as carbon dioxide, carbon tetrachloride and water, should not be used.

Surface Finishing

A vapor blast treatment, followed by pickling, is used several times during the fabrication process to remove light surface oxides resulting from the forming operation, welding or heat treating. The vapor blast machine shown in Fig. 8 uses 200-grit abrasive in water; the parts travel at a uniform rate under the blast nozzles. Following blasting, parts are pickled in a nitric-hydrofluoric acid bath (HNO_3, 39% by volume; HF, 2% by volume), then thoroughly rinsed in cold and hot tap water, followed by a hot deionized water rinse.

Figure 9 shows the pickle area. Pickling and rinsing are done vertically in tanks 12 ft. deep. A high-speed crane was devised to get parts in and out of the tanks as fast as possible. The surface treatment area also has a 12-ft. deep vapor degreasing tank which can be used to clean parts after machining and at other times when it is needed.

Both the hafnium control rod and the rhombus tube assembly are given a corrosion test in an autoclave (Fig. 10) using 750° F. steam or 680° F. water or a combination of both, using very high-purity water. This produces a thin, uniform film over the parts, similar to what is achieved in anodizing aluminum. Any areas on components where corrosion will take place show up in this test. A careful visual inspection is made of parts after the autoclave test to make certain the entire areas is uniformly coated with the oxide film. This is the best assurance that the part will perform without failure in service.

Fig. 10 – A Finished Hafnium Control Rod With an Adherent Oxide Film Emerges From Autoclave Test in High-Purity Steam. A uniform coating here is the best assurance that the part will perform without failure in service

Molybdenum Is Here To Stay

*Reported by J. L. McCLOUD**

Molybdenum is pre-eminent among metals for high-temperature uses and is solidly entrenched in the electronics industry and for missile parts whose working life is very short. Protective coatings have been perfected so gas turbine blades can run at 2000° F.
(Q-general, 2-62, T24e, T1, 17-57; Mo)

MOLYBDENUM has been favorably known as an alloying element – principally in engineering steels – since World War I. It is classed as a "strategic" element, since the most important mines are in the United States; we do not need to import it. It was early known to have as high a melting point as 4750° F. – in that sense it is a "refractory" element. In fact, it is refractory in other senses as well. It had been recovered in small amounts via powder metal techniques, but a decade of work was necessary at Climax Molybdenum Co.'s laboratories in Detroit before 400-lb. forging ingots were made (1950) by consumable-arc melting in a vacuum†.

It quickly was found that the high-molybdenum alloys had superior strength at high temperatures. They are stiff (modulus at 70° F. = 47,000,000 psi.) and have low coefficient of expansion. However, the oxide is volatile at low temperature, so they oxidize at truly catastrophic rates. Engineering use at high temperature required that this problem be solved. Once this could be done, the metal would be ready for many exacting roles in jet engines, supersonic planes, electronic gear, missiles, atomic reactors and chemical vessels. Julius J. Harwood of the Office of Naval Research said that molybdenum alloys have a combination of properties at temperatures above 1800° F. which are "unsurpassed by any other material evaluated thus far. In several instances, they are the only things now available which can even approach the increasingly severe requirements of advanced military weapons and equipment."

Surface Protection‡

That good progress has been made in this direction (largely in research programs supported by the Army and Air forces) was evident from papers read before a two-day Conference on Molybdenum Fabrication held by the Los Angeles and San Fernando Valley Chapters early in May. Many speakers referred to different aspects of this problem, although formal papers by R. I. Jaffee of Battelle Memorial Institute and M. A. Levinstein of General Electric Co. summarized the situation excellently.

Mr. Jaffee noted that many diverse methods were now available, each with its own advantages and disadvantages. A compromise is needed to select one for specific use. They are all coatings – often multilayer – which are applied to the molybdenum by a variety of methods. Sheet and simple shapes may be roll-clad with oxidation resistant alloys. Electrodeposition or electrophoresis (sputtering) is suitable for articles of somewhat more complex shape – also processes such as cementation, deposition from vapor or from salt or metal baths, hot dipping, brazing, or paint-and-sinter.

It would be desirable to find a coating which has the same high modulus and low coefficients as molybdenum itself – that is, one which will just hold on despite thermal shock, or scouring of fast-moving gas with some solid in it.

Metallic coatings for molybdenum almost invariably are nickel or nickel-base alloys, on the order of 0.002 to 0.003 in. thick. The reason is that, in the event that air enters either through a defect or by diffusion through the coating, the product of oxidation is nickel molybdate. This

*Consulting Editor, *Metal Progress*.

†See "Development of Arc-Cast Molybdenum", by Alvin J. Herzig, *Metal Progress*, July 1956, p. 103.

‡For a comprehensive discussion of this problem see "Protecting Molybdenum From Oxidation", by Alvin J. Herzig and J. R. Blanchard, *Metal Progress*, October 1955, p. 109.

is relatively refractory and not volatile like molybdenum trioxide nor fusible like iron molybdate. Unfortunately, nickel molybdate spalls during cooling and must be renewed on reheating. For this same reason, the nickel-type coatings are not too resistant to thermal cycling.

Chromium is usually present in order to improve oxidation resistance. In multilayer electroplated coatings, chromium is next to the molybdenum so as to retard diffusion of nickel and improve adhesion. The good ductility of nickel and nickel-chromium coatings fits them for applications where resistance to impact and formability are required. Such coatings will withstand a few hundred hours in air at 2000° F.

Roll-clad nickel has good impact resistance and bend ductility; Inconel is better at 1800° F. Such coatings are in part self-healing, starting to melt at about 2400° F. Edge protection is a large problem in all parts which are not plated after fabrication.

Sprayed coatings based on aluminum are somewhat less ductile than the nickel or nickel-chromium coatings, but have improved resistance to thermal cycling and erosion. Chief among these are the spray coatings of aluminum with refractory powders such as Al-Si-Cr. Although this is relatively brittle at room temperature, it has sufficient ductility when hot so that creep of the part does not impair its protective ability. This type of coating may be used to higher temperatures than nickel-base coatings and also has some self-healing tendencies.

Vapor-deposited or paint-and-sinter coatings, which have $MoSi_2$ as the external layer, are relatively brittle even at elevated temperatures. However, their maximum temperature of protectiveness is very high. Silicide coatings are also self-healing, since silica forms at any break.

Ceramic-type coatings have also been investigated, primarily at the U.S. Bureau of Standards. Usually they are combined with some sort of metal; otherwise they would offer little protection. Typical are mixtures of glass and Cr-Ni-B, or chromium powder plus frit. Such coatings are thick and very brittle at room temperature, but some plasticity in the glassy phase will permit limited deformation at high temperature without damage. If the part does not creep under load, chromium glass frits are useful up to 2800° F.

Mr. Levinstein's comments on protection of molybdenum can best be presented in combination with those by his associate R. C. Downey – a pair of papers giving the "Molybdenum Bucket Story". The information came from the design, construction and test operation of a test engine by General Electric Co., wherein much of the metal was molybdenum. The aim, of course, was to improve the thermal efficiency of a turbine by using gas at a higher temperature. The buckets operated at 2000° F. This "hot rod" engine has been successfully run for over 500 hr. – and that is really hot running! All this to test turbine buckets and advance the art of gas turbine design.

While the "hot rod" engine started as a modification of an existing engine, the study eventually embraced all steps from design through procurement, manufacture, coating development, testing of components and evaluation in a test vehicle. The basic alloy was molybdenum with 0.5% Ti and 0.07% Zr. The bucket design was such that the vane was air cooled next to its attachment to the wheel. These buckets were upset from bars, and precision forged and then machined. No exotic techniques were required and over 2000 finished buckets have been made. The stator blades were steam cooled. The entire rotor in the test engine was somewhat smaller than in a conventional design and it was air cooled. Ducts for the hot gas were lined with L-605 ("Haynes" Alloy No. 25: 0.15% C max., 20% Cr, 10% Ni, 15% W, 1.0% Si max., 1.5% Mn, 2.0% Fe max., balance Co).

Buckets and vanes were coated in various ways and then panel-tested at 1500° F. If successful, a second test was made at 1800° F. If the coating still looked good, the coated blades were mounted in an engine and tested at 2000° F. In the engine tests, attention was paid to endurance, thermal shock by cycling (shutdown and full operation) and erosion. The latter consisted of feeding the engine 4 pints of sand in 2 hr. and subsequently running for 25 hr.

Some notes on the coatings evaluated in this way were recorded by Mr. Levinstein:

Chromium plating wasn't adequate; 20 sec. at 2300 to 2400° F. ruined the blades, and any metal coatings must withstand this temperature during surges or at hot spots. Nickel coating seemed to be good in the panel tests, but gross damage by impact during running wasn't realized until the engine was taken down. When Inconel is coated over molybdenum, a diffusion zone grows at the intermediate layer in long tests – 1600 to 2000 hr.

Nichrome cladding, 6 mils thick, was laid on in an argon chamber, using titanium as a getter to remove last traces of oxygen. It lasted 50 hr. at 1800° F., but 90% of the blades failed rapidly at 1900° F. A chromium oxide ceramic coating

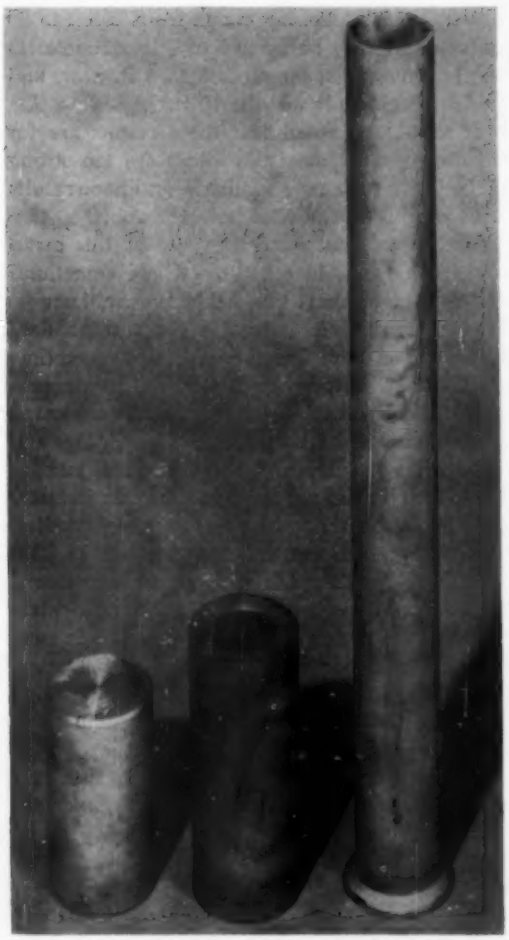


Fig. 1 – Sequence of Operations in Cold Extrusion of an Unalloyed Molybdenum Tube. Left: starting slug, machined from bar stock. Center: cup, back extruded at 38% reduction. Right: tube, forward extruded at 74.6% reduction

was also tried, but the results seemed to indicate that ceramics or cermets are not as good as the two now to be mentioned.

Good results were had from a Ni-Si-B mixture, flame sprayed and diffused by heating in dry hydrogen. Thickness is 5 to 6 mils, increased to 12 mils at the leading edges of the buckets.

All in all the preferred plating is a triple plate, chromium then nickel then chromium, to a total of 0.004 in. Temperature of the plating bath is important; cleaning prior to each plate was done with the help of ultrasonics. Finally the piece was heat treated so the various layers would mutually diffuse to a small extent.

The engine tests indicated that "dovetail cracking" was the biggest trouble. Its cause was overstress in engine operation. Completely uniform loading is impossible if for no other reason than tool marks left from the machining. Notches lower the strength and stress concentrations lead to failure. Considerable deterioration was noted along the trailing edges of the buckets, but the General Electric engineers seemed to think that minor cracking on the trailing edges isn't fatal. Sand impact may cause erosion without actual failure of the cladding.

After listening to this presentation, this reporter acquired the idea that molybdenum blades with proper coatings can be operated for long periods of time up to 2100° F., and that they are more desirable in this exceedingly severe service than ceramic blades. Even higher temperatures can be withstood as soon as better cladding can be devised.

Residual oxides, nitrides and carbides occupy grain boundaries in the as-cast ingots (or castings) and reduce ductility; nevertheless a little carbon is relied upon to help deoxidize the vacuum-cast ingot. (It isn't economic to double-melt; purer metal to start with is preferable.) Oxygen may even get into hot sheet through bare cut edges and cause trouble. Surface contamination is quite possible – in fact, you don't have to "roll in" the oxide. Descaling by chemical means is required; annealing should be done in a controlled atmosphere. There can, of course, be mechanical cleaning such as sand-blasting or vapor blasting. Hot working in an inert atmosphere will undoubtedly improve the final properties. A room to permit such an atmosphere and at the same time allow human control is being designed; its construction is 9 to 12 months away.

For true hot working, molybdenum should be forged and rolled above 3000° F., but available fabricating facilities for large sections are limited to 2300° F. Therefore, molybdenum is technically "cold worked" from the ingot to the finished bar, sheet or forging. This cold working influences the properties to a great extent.

As pointed out by G. A. Timmons of Climax Molybdenum Co., molybdenum has no phase change, therefore the properties cannot be improved by heat treatment; higher hardness and strength are obtained by cold working. Additions of alloying elements which go into solid solution (such as Ti, Zr, V, Cb) increase the rate of strain hardening and raise the recrystallization temperature, thereby raising the temperature at which the properties developed by cold working may be used to advantage. Alloys that can be commercially produced are now capable of sustaining stresses of the order of

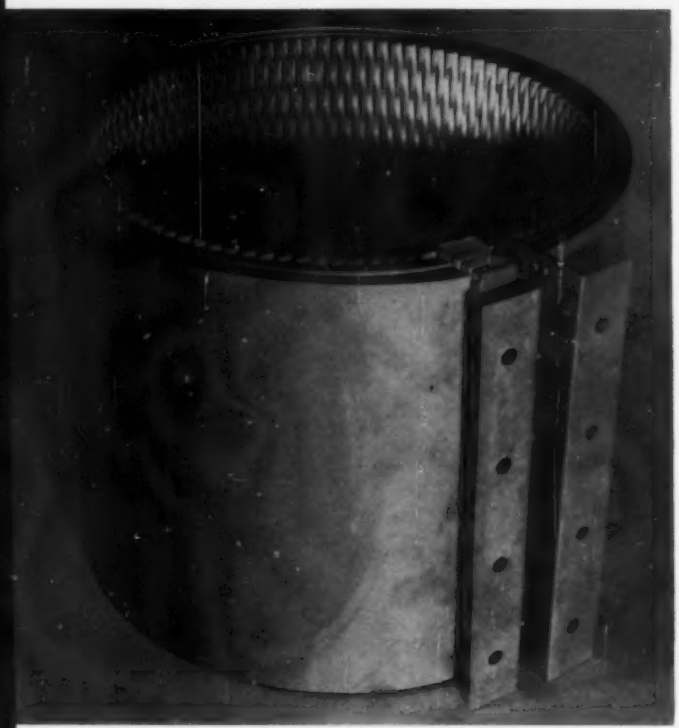


Fig. 2 – Expanded Metal Sheet Used as a Heating Element in Vacuum or Hydrogen Furnaces for Degassing or Firing Tube Components. (Courtesy Fansteel Metallurgical Corp.)

50,000 psi. at 2000° F. for 100 hr. before rupture. Some need more than 2500° F. for recrystallization, whereas unalloyed molybdenum recrystallizes at 2100° F.

Since metal at the working temperature for molybdenum radiates heat quite rapidly, the time available for working after leaving a furnace is very short. Consequently extrusion is preferred for preliminary breakdown. Sheets up to 36 in. wide are now available. Strengths of 125,000 psi. with 11% elongation have been reported "with the grain" on 0.010-in. sheet. Annealing (stress-relieving) is at 1900° F., although there is some opinion that longer time (up to 90 min.) at 1700° F. is preferable.

Ingots are now available up to 2500 lb.; extrusions to 6 in. diameter and 1800 lb.; bars 1½ × 7 in. weighing up to 330 lb. Incidentally extrusion in the usual 2:1 or 3:1 ratios doesn't work the center of a bar, and if bars are upset, a hidden flaw may be disclosed. Front-end bursts cause excessive cropping losses. However, R. A. Quadt of Hunter Douglas Aluminum Corp. reported commercial production of tubing by steps illustrated in Fig. 1. The tube wall is concentric to 0.002 in.; thicknesses range from ¼ in. to 30 mils; tubing may be up to 5 or 6 in. diameter in the heavier walls; length is 5 to 6 ft. now, and perhaps ultimately may be 10 ft.

It should be noted that these results are for unalloyed metal; the cold alloys are too strong and stiff for tools now available, and poor results have been achieved with hot extrusion.

While the most interesting use of this metal and its alloys is in missiles – where sometimes life may be so short that oxidation problems no longer control – it is in the gas turbine field that molybdenum has its important peacetime applications. Otherwise in ultrasonic parts, protected sheet will be useful for surfaces subjected to aerodynamic heating, for nozzle openings and honeycomb structures. They are resistant to liquid metals and are used in the glass industry for stirrers, for boring bars and grinding spindles.

It was pointed out that for operation at 2000 to 3000° F., with a life from seconds to hours, molybdenum has been used for years in glass manufacture and in electronics. Sheet is in most demand, with extrusions and tubes following. The high strength, high melting point, high modulus, and low coefficient of expansion are of importance in these applications.

R. Yancy of Fansteel Metallurgical Corp. said that, in the electronics industry, moly is like your wife – somewhat unpredictable but must be lived with! It is used in vacuum tubes, especially the plates and grid wires of the larger designs, since they operate at greater power and are progressively hotter. Designs have been changed as the material available has improved; in fact molybdenum alloys have been used above 4500° F. Cathode supports operate regularly at 3600° F. The good thermal conductivity keeps the temperature down and low vapor pressure maintains the vacuum in the tube. It also readily forms metal-to-glass seals.

The rapidly growing petrochemical industry may soon be using significant amounts of molybdenum. Its resistance to mineral acids, even at temperatures of 600 to 700° brings it into competition with tantalum and zirconium. In this field tubing has the greatest interest. Small extruded tubes, ½ to 1 in. diameter with wall of ⅛ and ¼ in., now replace tubes formerly bored out of rods and used as steam lances or in heat exchangers.

Altogether, it would seem that molybdenum has been rapidly growing up during the past decade. It was disclosed that a $1,000,000 plant will be built at Coldwater, Mich., before the year's end to supply more mill shapes.

Powder Metallurgy of Uranium and Thorium

*By ALAN BLAINEY**

Powders derived from alternative production methods vary greatly in size and shape, thus affecting "compactibility" either hot or cold. Surface oxide or compounds may prevent atomic diffusion across particle boundaries during sintering and result in weak or brittle parts. Cermets made from oxide or carbide particles have been used extensively in test reactors and components. (H-general, T11, 17-57; U, Th)

POWDER METALLURGY in its theoretical and practical aspects has been given much attention in recent years in Great Britain. This is especially true in the nuclear power program. The fissionable and breeder elements (uranium, plutonium and thorium) are reduced from purified chemical compounds into powder form. Likewise, many of the fuel cladding and dispersant materials in the reactors (notably beryllium and zirconium) are made in a similar way or go through processes where they are "atomized" or are condensed from the vapor phase. Reconsolidation of these powders into strong, compact and useful shapes is of course a necessity.

Even if this were not true, it would often be desirable to start with finely comminuted metal. For example, uranium (either natural or slightly enriched in U^{235}) is the most economical fuel. Unfortunately, it has an allotropic transformation with large volume change at 668° C. (1235° F.) – so large a volume change that it cannot be endured in a rigid structure, and to avoid it the temperature must be kept too low for desirable heat transfer systems. Manufacture of porous masses, use of uranium oxide, carbide or other compounds, or alloying to minimize the transformation effect – all methods using powder metal technique – are therefore of much interest.

Furthermore, the uranium must be protected from corrosion or dusting into the cooling medium. Heat transfer must not be interfered with, and this means that there should be the most intimate contact between fissionable metal in the core of a fuel element and the corrosion resistant sheath. Here again powder metallurgical processes have considerable possibilities.

While comparatively few metallurgists have an active part in these absorbing studies, the findings from the atomic energy laboratories have such wide application to more work-a-day problems that a general description is warranted. It is therefore proposed to present a series of articles reviewing recent British developments in powder metallurgy, discussing in turn fuel elements, fuel containers, beryllium, and sintering and compacting techniques.

Uranium – In contrast to American practices wherein uranium powder is produced by converting massive metal into expensive hydride, the aim of the British work was to produce the uranium powder by direct reduction of urania. Although the oxide can be reduced by carbon, temperatures in the region of 3600° F. are required for the reaction to proceed and massive metal, not powder, would be formed. Uranium powder is therefore produced by reducing urania with calcium or magnesium.

In the early experiments, standard urania (as prepared for UF_4 production) was used, but this powder proved to be unstable on storage in air due to variable oxygen absorption. A more

*Adamant Research Laboratory, Anglo-American Corp., Johannesburg, Union of South Africa; sometime Powder Metallurgist, U. K. Atomic Energy Research Establishment, Harwell, England. Manuscript submitted October 1957. Much of the work described here on powder metallurgy as applied to nuclear power development was carried out many years ago, but has only recently been declassified, and may not necessarily represent present-day thought and techniques.

stable oxide was therefore made by decomposing ammonium diuranate at higher temperatures. The "stabilized" urania is mixed with 30% excess of calcium granules (−6+20 mesh) and carefully transferred to a vessel of the form shown in Fig. 1. After evacuation, the vessel is filled with argon and heated slowly to about 900° C. (1650° F.). The reaction occurs spontaneously and the internal temperature rises to about 1600° C. (2900° F.), resulting in the formation of minute droplets of molten uranium which remain dispersed in the calcium oxide which is formed. After cooling, the reaction cake is knocked out of the vessel, separated from the lining, and crushed to −18 mesh, then leached with nitric or acetic acid at 20 to 30° C. to dissolve all the calcium oxide, washed and vacuum dried for several hours.

Figure 2 shows samples of the powder particles. A is mainly particles of primary uranium; B represents the secondary particles, spheres formed by coalescence of primary particles; C shows filigree particles formed from primary particles; D is a coke-like particle at lower left, possibly formed as an intimate dispersion of uranium and the Ca-CaO slag. Such particles tend to be pyrophoric and a mass of dry powder can burn spontaneously. For safety it is best stored under argon in a special container which allows it to be transferred to compacting dies under an argon blanket. If required for hot compacting, the powder may be stored under kerosene or the particles coated with a film of paraffin wax.

Sintering, hot compacting, and alloying of such powders were extensively explored by Blainey, Lloyd and Williams at Harwell. Due to the spherical shapes, cold compacting was not very successful; the particles deformed so little that the oxide films did not rupture; no "cold welding" occurred. Vacuum annealing at about 800° C. (1475° F.) improved compactibility somewhat, but further densification during sintering at about 1000° C. in vacuum was slowed down, apparently due to the formation or alteration of surface films on the particles which interfered with diffusion of the metal across the interfaces. Indeed, it was found that *uncompacted* powder in an alumina tube or boat could be sintered to about 97% of theoretical density, and the resulting slugs could be cold rolled or swaged to over 90% reduction.

Calcium-reduced uranium powder was extruded into ¼-in. rods through Stellite or cemented TiC dies at about 800° C. (1475° F.).

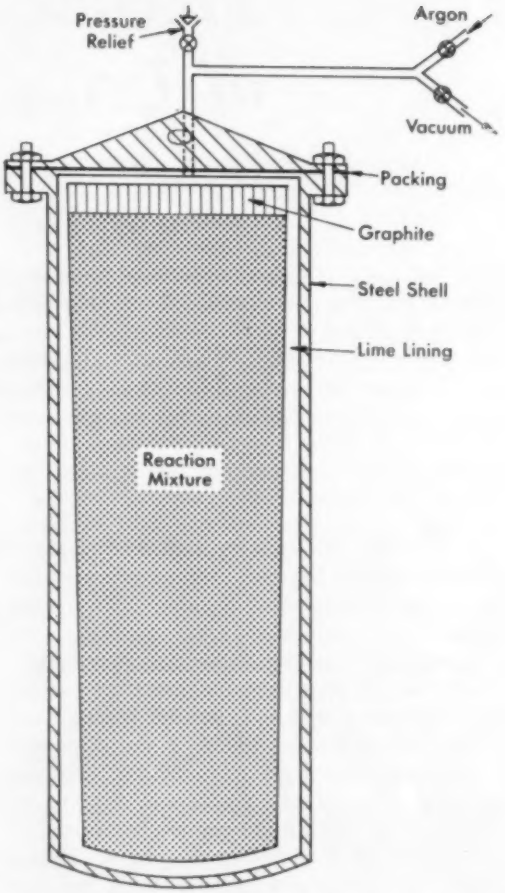
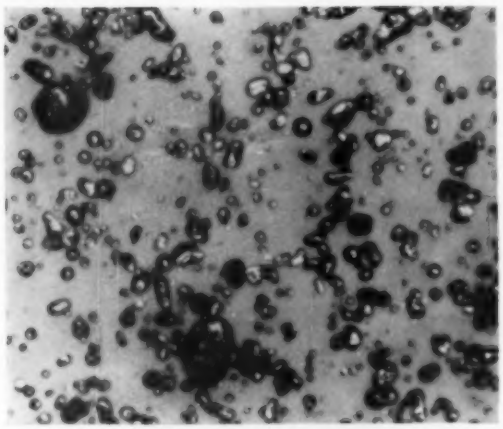


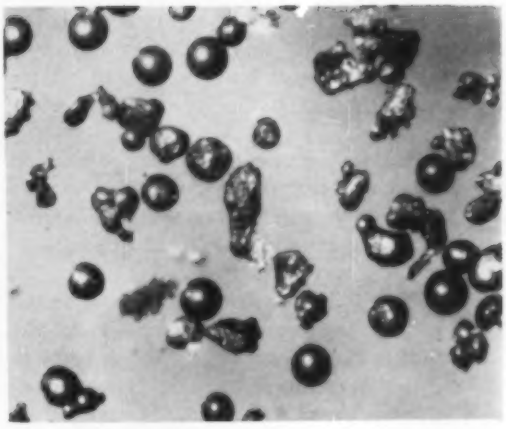
Fig. 1 — Sketch of Reaction Vessel for Preparing Uranium and Thorium Powders by Reducing "Stabilized" Oxides With Calcium Granules. (Courtesy Industrial Review of Africa)

The Stellite was sometimes attacked by the erosive action of gamma uranium, and the TiC was very liable to fracture. These troubles were corrected by using Nimonic-80 or 90 dies coated with a 0.005-in. layer of zirconium alloy. The powder was also extruded into 1-in. rods after enclosing the material in a copper canister and heating to 600° C. (1100° F.), very much higher pressures being required.

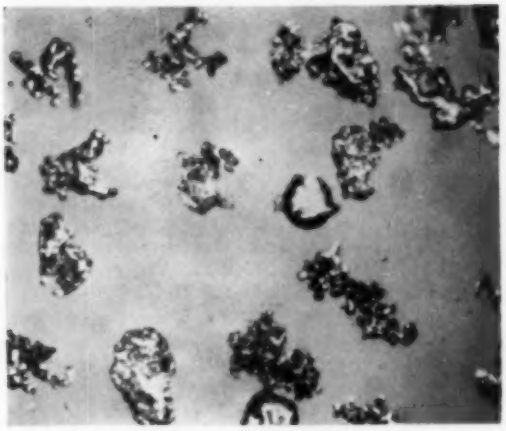
Magnesium-Reduced Powder — Magnesium for reducing urania has certain advantages over calcium. It is cheaper, more easily obtained pure and is not contaminated with nitride by exposure to air, as is calcium. (Calcium can be largely freed from nitride by treatment with low-pressure water vapor which forms ammonia.) However, magnesium has a much higher vapor



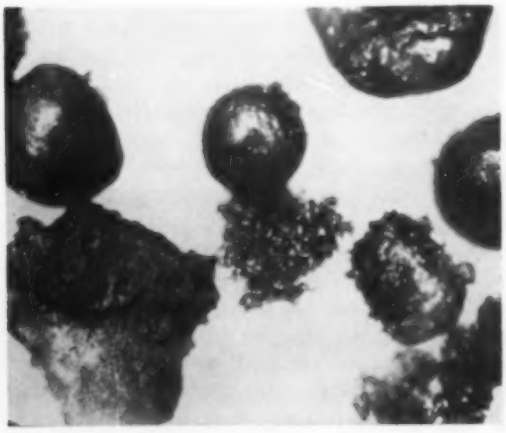
A – Primary Particles; 200 ×



B – Spheroids (Coalesced Primary); 20 ×



C – Filigree (Primary Groups); 100 ×



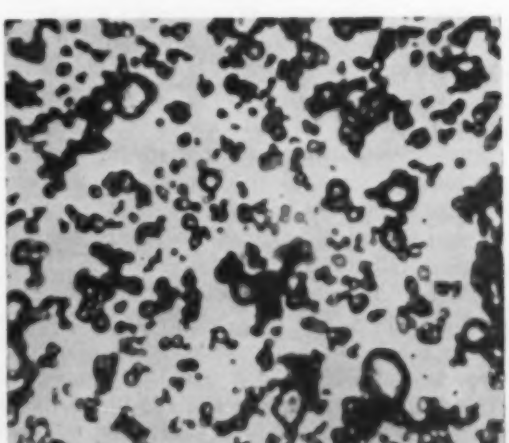
D – "Coke-Like" at Lower Left; 1000 ×

Fig. 2 – Uranium Particles After Freeing Them From Ca-CaO Slag

pressure than calcium, resulting in extensive reaction at lower temperatures. Furthermore, the heat of reaction is less (particularly above the boiling point of magnesium, 1107° C.) and this, coupled with the heat absorbed by vaporization of excess magnesium, keeps the reaction temperature well below 1200° C., resulting in the formation of extremely fine, pyrophoric particles of uranium.

To produce spherical particles, it is necessary to add a flux (10% of $MgCl_2$) and to heat the reacted mixture to 1200° C. for up to 2 hr. The powder so produced, shown in Fig. 3, is considerably finer than the calcium-reduced powder and may be pyrophoric, but it can be fabricated in the same way. Its small particle size (average 4 microns) may even be of advantage for fabricating stable fine-grained uranium of ran-

Fig. 3 – Magnesium-Reduced Uranium Powder. 600 ×



dom orientation, since films of uranium monoxide, carbide, silicide, or some other refractory nonreactive substances may be formed on the particles to restrict grain growth of material compacted hot.

The extremely fine powder produced without flux might be used if material of still finer grain size is required; special handling techniques would then be required to avoid exposure to oxygen.

These uranium powders have been mixed with various proportions of magnesium, aluminum, beryllium or zirconium (the uranium particles sometimes being coated as mentioned above, and compacted hot). Temperatures were 500 to 600° C. (925 to 1100° F.) for magnesium and aluminum, and 850° C. (1550° F.) for beryllium and zirconium. While interaction between aluminum and beryllium with uranium — even when coated — was observed, sheaths of each of these four metals were compacted around the mixed powders to form a complete covering or container.

Uranium alloys containing varying percentages of molybdenum, columbium, zirconium, and thorium were made by vacuum sintering compacts of the mixed powders. Some of these alloys were also prepared in powder form by calcium reduction of the mixed oxides, but it is difficult to disperse the oxide sufficiently well to insure uniform composition of all the powder particles. The only satisfactory way of insuring uniformity, apart from co-precipitation of the oxides — and this is hardly possible for the above mixtures — is prolonged grinding of the mixed oxides before reduction.

The alloy powders were fabricated by sintering and hot compacting, the latter process being used to make uranium bars with alloy layers of graded composition by arranging a suitable disposition of powders in the compacting die. A technique was developed for hot compacting long bars at temperatures up to 750° C. (1375° F.) from a number of cold compacted pellets of waxed powders, the wax vapor serving to form a protective atmosphere. These pellets were compacted between opposing plungers in a split tapered sleeve die made of Stellite and held in an electrically heated Nimonic-80 bolster. They could be compacted to a diametrical tolerance of 0.2%, about 500 such bars being obtained before this figure was exceeded due to die distortion. Although the compacts lacked ductility (due to interparticle oxide-carbide films), heat treating at 850° C. (1550° F.) corrected this by spheroidizing the films; the bars could then be worked mechanically.

The finer powder produced by magnesium reduction was compacted in the same way.

Alan Blainey

After education at Manchester and Liverpool and work on light metals with High Duty Alloys, Ltd., and on powder metals with Hard Metal Ltd. and Parnall Aircraft Ltd., he joined the staff of the U. K. Atomic Energy Research Establishment at Harwell in 1946. After nine years of work on nuclear metals and fuel elements, he transferred to the research staff of the Anglo-American Corp. of South Africa. Ltd.

Thorium

Thorium powder has been produced in England in a large pilot plant by reducting thoria with calcium chips, and without flux. Consequently, the powder was very fine and had up to 0.4% oxide. Compacting pressures up to 65 tons per sq.in. were explored, and a value of 25 tons was finally adopted as the optimum value, giving the minimum of entrapped air. Sintering temperatures in the range of 900 to 1350° C. (1650 to 2450° F.) in a vacuum of about 0.04 micron of Hg were explored, the compacts being contained in an evacuated mullite tube and supported on a molybdenum grid which could be moved in or out of the hot zone while in the vacuum.

Sintering rate was found to increase rapidly above 1200° C., and 1300° C. (2375° F.) was chosen for further experimentation. The principal limitation was the rapid interdiffusion of the thorium with the supporting molybdenum grid. Under the above optimal conditions, 2 hr. gives compacts with density of 11 g. per cc., but impracticably long times (of the order of 25 hr.) would be required to obtain reasonably close approach to 11.79, the theoretical density.

It was therefore decided to cold roll the slugs 50% and then resinter 2 hr. at 1300° C. This resulted in metal with a density of 11.65 g. per cc.

The microstructure showed blue-gray inclusions of thoria and a hard white phase, thought to contain iron. The mechanical properties of the resintered thorium range as follows: ultimate strength 33,500 to 26,300 psi., elongation 18 to 40%, reduction of area 14 to 35%, Vickers hardness 72 to 74. Heavily cold worked rods had ultimate strength of 86,000 psi.

The above findings by Smith and Honeycombe contrast sharply with the results of early work at Harwell by the present writer with "Degussa" thorium powder (reduced from thoria in the presence of $CaCl_2$ flux) both alone and mixed with small amounts of uranium, beryllium and other powders. Compacts pressed at 56 tons per sq.in. were vacuum sintered at 1000° C. (1825° F.) for 2 hr. The pieces made of thorium only had a density of 11.6 g. per cc. and this (as well as some of the alloys) could be extensively cold worked by hammering without visible cracking. The difference can probably be explained by the large particle size of the Degussa powder and its relative freedom from thoria.

Uranium and thorium powders have also been made by magnesium reduction or by electrolysis of molten chloride mixtures. The UCl_3 or $ThCl_4$ was formed in the melt by reaction of the oxide with chlorine – sometimes in the presence of iron chloride as catalyst – the oxygen being removed as SO_2 or CO by potassium sulphide or carbon also present. This process probably has a wide field of application in the reduction of BeO, ZrO_2, TiO_2 or Cb_2O_5. A cursory investigation of the consolidation of the above thorium powders showed that the magnesium-reduced powder gave higher compact density, but both were better than powder prepared by calcium reduction of thoria, although the latter had the highest bulk density. After sintering, the compacts prepared from the electrolytic powder had the greatest ductility.

This installment will be closed with a brief description of some experimentation in ceramic fuels, which for our purposes will be defined as oxides and carbides of uranium and thorium. Sintering and compacting have been extensively studied by Murray and others at Harwell.

Fabrication of Ceramic Fuels

The optimum conditions for slip casting both oxides were determined. The size and size distribution were modified by grinding so as to give good packing which is essential for strong slip-cast bodies of reasonable density (70% of theoretical). Best results were obtained with a pH of 2.1 for the urania slip and 1.0 for the thoria slip. For urania, the highest sintered densities (for example, 10 g. per cc. by sintering at 1400° C. or 2550° F.) were obtained by using an oxide of composition $UO_{2.13}$*. Translucent thoria of 9.64 density was produced by presintering the slip-cast articles at 1350° C. (2460° F.), followed by final sintering at 1825° C. (3300° F.). Such material is substantially free from open pores.

Urania and thoria were also fabricated to about the same densities by hot compacting in graphite molds at a pressure of about 2250 psi. The highest density urania was again obtained with $UO_{2.13}$ by hot compacting at 1900° C. (3450° F.), but some UO_2 was reduced by contact with the graphite mold, thus producing a shell of material which resists deformation and results in internal voids. This should be corrected by higher compacting pressures.

Thoria was compacted at 1900° C. (3450° F.) to produce a material of 9.78 density. Higher temperatures caused excessive grain growth. At temperatures below 1700° C. (3100° F.), higher densities were obtained if the material started as thorium carbonate, due to the increased surface activity of the thoria immediately after its formation therefrom.

Monocarbide of uranium produced by reaction of urania and carbon for 10 hr. at 1900° C. (3450° F.) was ground under trichlorethylene to the required particle size (10 to 100 microns) and dried before use, being manipulated in argon dry boxes to avoid spontaneous combustion. The particles were about 8% porous. Hot compacting in graphite dies was unsuccessful due to the formation of UC_2 (by reaction with the die)

*Editor's Footnote – Such a formula seems impossible to one whose chemistry instructor held that compounds had stoichiometric ratios. Dr. Blainey says this formula is caused by the presence of "mobile centers" in the solid particles – positive holes or vacancies which facilitate self-diffusion in the oxide during sintering.

which is unstable in moist air. Sintering at 2000° C. (3600° F.) of axially pressed compacts yielded material of density 12.1. Sintering of isotropically compacted tubes gave a density of 12.0, the maximum value for a tube sintered at 2100° C. (3800° F.).

Iron, nickel, cobalt and uranium binders were explored during the fabrication of UC cermets. The transition metals, although satisfactory from a fabrication point of view, absorb too many thermal neutrons for use in thermal reactors; nickel and iron, might, however, find application in fast reactors. Cermets bonded with uranium were formed by reaction of carbon and uranium powder. (They might be produced by direct reaction of UO_2 and carbon at about 2000° C. in vacuo.) The mixture was hot formed to desired shapes by compacting or extrusion at 650 to 800° C. (1200 to 1475° F.), as described previously for uranium powder, followed by heat treatment at 1000 to 1100° C. (1800 to 2000° F.) to form the carbide. With a total carbon content less than 2%, the UC phase tended to coalesce; from 2 to 4% carbon it formed a stable network intermeshing with the uranium. Above 4% carbon, isolated uranium particles in a carbide network were formed.

The high-temperature strength of these mate-

Improved Methods for Deep Drawing

By OUR SPECIAL CORRESPONDENT

Equal ductility in both directions – longitudinal and across rolling direction – is desirable for deep and difficult stampings. Steel and aluminum sheet, as well as new metals such as beryllium and zirconium, may be improved in this manner by the same techniques as control the direction of crystallization of iron-silicon transformer sheet. (G4b, Q23q)

REGIONAL CONFERENCES by groups of neighboring ASM chapters tend to concentrate on single topics of current importance. An example is the Southern Metals Conference held by 11 chapters late in April at Gatlinburg, Tenn., where forming of sheet metals was discussed. It was an interesting affair, not only for the practical information about plant practices on carbon steel and stainless sheet, but for the theoretical or scientific speculation about how drawability of the commercial product might be improved.

Low-Carbon Steel Sheet

In the opinion of J. Warren Stewart of the Applied Research Laboratory, U. S. Steel Corp., there is a most appropriate grade of steel sheet for every part. Regular "drawing quality" will usually perform as well as aluminum-killed deep drawing steel in making deep drawn parts of symmetrical shape. Difficult unsymmetrical draws lead to trouble; drawing-quality special-killed steel is then more satisfactory, due primarily to better drawability in the longitudinal direction. Correct orientation of the part and the rolling direction also aid in avoiding rejects.

A study made by the Acme School of Die Design Engineering during 1951 to 1956 showed that failures during deep drawing could be attributed to die design 62% of the time, to die-making factors 19%, and to deficient properties of the metal stock in only 3% of the cases studied – a statement which was received by several field metallurgists present with some such reaction as "That's fine, if you could only make your customer believe it!"

Mr. Stewart said that U.S. Steel is conducting

rials, particularly those with a continuous carbide phase, is good – on the order of 22,000 to 33,500 psi. modulus of rupture at 1000° C. (1800° F.).

Very little work appears to have been done on the fabrication of Th-ThC cermets analogous to the above. In the early work at Harwell, thorium alloys containing fractional percentages of carbon, added as fine graphite, were prepared. As cold compacted and vacuum sintered at 1000° C. (1800° F.), they consisted of thorium grains surrounded by a discontinuous phase considered to be a ThC-Th solid solution. Massive compounds ThC and ThC_2 were prepared in the same way, the latter rapidly disintegrating by reaction with atmospheric moisture.

Continuation

This completes a brief summary of recent British work on the powder metallurgy of uranium and thorium. Much information on similar aspects of plutonium was given in the Conference on the Metal Plutonium held at the Chicago meeting of the American Society for Metals last fall, due to appear in book form later. The second installment of the present article will concern itself with the powder metallurgy of fuel cladding materials and moderators.

a major research project to discover a less costly nonaging steel whose surface characteristics will be as good as rimmed steel but will not drop in ductility and produce stretcher strains after storage at room temperature. High cost is the principal disadvantage of the vanadium-treated steel now available to meet these requirements.

These studies include work on the properties of sheet products as they are affected by processing variables. For example, sheets which have no marked yield point nor stretcher strain when formed at low speeds may acquire both at high rates of deformation.

There is a great need for a simple test that will correlate well with the performance of the material in practice and which can be readily used by production personnel. It is generally agreed, for example, that an isotropic material with a high capacity for work hardening is most suitable for symmetrical drawing operations, but how can such steel sheet be distinguished, easily and unerringly? In the laboratory it has been found that if a tensile test is made which records *true* stress against *true* strain (rather than apparent stress versus average strain) the results can be correlated to drawability. Two measures of anisotropy have been found to correlate well with performance in unsymmetrical drawing operations. One is the ratio between strain in the two directions – width and thickness – in a tensile test when the strains are measured just prior to necking. The other is magnetic torque.

Austenitic stainless has been much used in industry, and the talk about manufacturing aspects by Charles R. Mayne of International Nickel Co. led to an extensive discussion of the theoretical aspects of plastic flow. Since plastic deformation ("cold" working) is done by stresses of magnitudes somewhere between the yield strength and the tensile strength, it is desirable that the spread between these be as high as possible. In this regard, Type 302 stainless steel (18-9 Cr-Ni, 0.15 max. C) is ideally suited for fabrication by all conventional methods; however, the required power may be up to 50% over that for low-carbon steels.

Mr. Mayne recommended die radii of five to eight times the metal thickness, punch radii greater than four times the thickness, and speeds of 30 to 50 ft. per min. as the optimum conditions for deep drawing of austenitic stainless. Faster speeds result in local heating. The hold-down pressure on drawing blanks is another important factor in controlling wrinkling and thickening of the wall. Although "flexible-die" drawing is more expensive and has a lower production rate than conventional deep drawing, more uniform wall thicknesses are possible.

Effect of Interstitials – Sheldon E. Weinig of Materials Research Corp. predicted that intelligent use of what we know about crystalline architecture would, in all probability, help us to improve the ductility of metallic alloys. For example, austenitic stainless steels can possess an excellent combination of strength and ductility since these properties are derived from the austenite-to-ferrite transformation during deformation. Much of the strength is obtained from the quasi-martensitic structure resulting from the partial transformation; however, this does not explain the relatively large ductilities obtained. Much of this 70 to 80% elongation is

contributed by the strain (change in dimension) occurring during the martensitic transformation.

Attacking the problem of ductility in titanium alloys from this angle, Mr. Weinig suggested that if a beta-stabilized alloy could be found in which the stress required for deformation of the *beta* phase is less than the stress required to cause transformation, the total elongation the alloy could endure would have two components — (*a*) contributions from deformation of the beta-transformation strain, and (*b*) deformation of the remaining alpha phase. Such an alloy is a titanium-molybdenum alloy containing a small amount of oxygen. Uniform elongations of 33 to 44% have been obtained in such alloys as compared to elongations of 17 to 24% for specimens that were not beta-stabilized and oxygen-infused. Unfortunately, the control of the oxygen content is difficult; a slight excess leads to extreme brittleness.

The precipitous decrease in ductility of titanium and zirconium at approximately 0.6% oxygen by weight may be due to the pinning of imperfections. On this assumption, the problem of severe interstitial effects on the mechanical properties may be similar to interactions between dislocation and solute atoms, leading to such a phenomenon as the inhomogeneous yield point. It has been found, for example, that the uniform ductility of titanium containing 0.2 at.% oxygen could be increased from 13 to 20% by raising the annealing temperature from 1025 to 1475° F. and quenching. This increase in ductility may be due to fewer solute atoms segregating at the imperfections. It was also suggested that the embrittling effect of hydrogen in zirconium is due to a similar mechanism rather than to the appearance of a hydride phase.

Grain Orientation — In a paper summarizing some effects of grain orientation on the properties and fabrication of metals, C. J. McHargue of the Oak Ridge National Laboratory first showed why preferred orientations develop and how they are represented. A number of specific examples were cited on the relation between orientation and properties: Silicon-iron transformer sheet is a tonnage product in which texture is used to improve the product. By such control of grain orientation, the initial plastic properties can be varied by a factor of 1.67 in face-centered cubic metals (rod or wire). The use of grain-oriented steels for stators of generators will reduce core losses up to 36%. Although beryllium has the reputation of being extremely brittle, Nuclear Metals Inc. has produced sheet with ductilities in the plane of rolling of 30 to 40%. This two-dimensional ductility was achieved by application of knowledge about the deformation mechanisms of single crystals and the control of the sheet's texture.

Mr. McHargue concluded by discussing some ways of avoiding strong texture. In general, a proper fabricating schedule can only be developed by trial and error. Some successes have been achieved by variations in the amounts of reduction and temperatures in a series of rolling and annealing treatments, by cold stretching before annealing, by increasing the amount of a hard second phase, and sometimes by cycling through a phase transformation.

G. M. Young, of the Aluminum Co. of Canada, Ltd. (and president of A.S.M.), noted that the difficulties in nonsymmetrical drawing are not endemic on any particular metal. Metal stock with a random orientation, which may work excellently in symmetrical draws, may fail or produce "ears" in rectangular draws because of the flow patterns at the corners. In practice, it is always better to use material with a texture which will give improved ductility in the directions which undergo the most elongation.

Roller forming is an adaptation of the old spinning process where a flat plate (sometimes of uneven thickness) is faced back over a revolving mandrel by a small roller held in a tool steady-rest. The process, as applied in the aircraft industry to semi-austenitic steels, was described at length by Frank Jacobs of Temco Aircraft Corp. at the Southwestern Metal Exposition in Dallas in May. Such roller forming or power spinning (as described by Robin O. Williams of the Cincinnati Milling Machine Co.) uses a roller to flow the metal along a mandrel and reduces the wall thickness by a shearing action. Its advantages over conventional spinning are (*a*) it is possible to control wall thickness and reduction; (*b*) it is possible to make very large shapes of tough materials; (*c*) shapes such as tubes and parts with unusual contours can be produced; and (*d*) tool costs are reduced.

"Hydroforming," or flexible-die drawing, competes with conventional drawing for limited runs. Greater reductions can occur, because there are no high stresses at the radius where the metal enters the die. Since only a single die is required and they do not break, savings of 50 to 80% in die costs are realized. The more natural flow paths of the metal result in a greater uniformity of wall thickness in the pressing. However, hydroforming is considerably slower than conventional drawing and, therefore, unsuitable if high production rates are needed.

W-545... a Better Turbine Disk Alloy

*By J. T. BROWN**

A new iron-base turbine disk alloy having a good combination of high-temperature stress-rupture strength and ductility, and low-temperature tensile strength has been developed. Boron in amounts from 0.005 to 0.15% increases the inherent ductility of the present austenitic precipitation hardening alloys. Further strengthening, by additions of larger amounts of titanium, is then possible without allowing the material to become notch sensitive. (Q-general, T7h, 17-57, 2-62; Fe, SGA-h)

DEVISING NEW superalloys is really quite simple – all you have to do is increase the operating strength, or the temperature, or both. And that's easy, too. You merely add more precipitation hardening elements to an already existing alloy. Sounds too good to be true – and it is. Unfortunately – and this is the problem – a loss of ductility usually accompanies the increased strength gained in this manner. However, if the ductility is increased in some manner, a greater amount of hardener can be used – and the problem is solved. How this was accomplished with a typical precipitation hardening alloy is the subject for this article.

Ductility is intimately connected with notch sensitivity (defined as the failure of a notched bar in less time than an unnotched bar under the same stress-rupture conditions). When unnotched ductility is above 5% elongation, the alloy is reliably notch ductile; the 2 to 5% range is a twilight region; below 2% the alloy is notch sensitive. (We operate on the principle that an unnotched ductility below about 5% elongation renders a material unacceptable for aviation gas turbine disks.)

The Generalized Boron Effect

The addition of 0.005 to 0.15% B to Discaloy, a precipitation hardening alloy, greatly increases the inherent ductility for equal rupture time in

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Table I – Stress-Rupture Tests at 1200° F. and 70,000 Psi.

Boron	Plain Bar			Notched Bar	
	Rupture Time	Elongation	Hardness Before/After	Rupture Time	Hardness Before/After
0.000%*	38 hr.	3.5%	C-33/33	16 hr.	C-32/32
0.002	28	3.7	31/31	14	31/31
0.006	32	6.0	32/32	35	31/31
0.02	25	10.0	31/31	44	31/31
0.06	27	14.2	31/31	52	31/31
0.12	25	18.1	31/31	56	30/30
0.000†	93	1.6	31/35	5.7	31/35
0.002	102	1.8	32/35	9.0	31/35
0.006	95	2.9	31/35	44	31/35
0.02	99	4.0	31/35	83	31/35
0.06	109	7.5	32/36	155	31/35
0.12	95	8.5	31/35	156	31/35

*Standard age—20 hr. at 1350° F., cool to 1200° F., hold 20 hr. at 1200° F.
†Genuage—16 hr. at 1200° F., heat in 16 hr. to 1300° F., hold 12 hr. at 1300° F.

stress-rupture tests. Because of this increase, greater percentages of titanium (the precipitation hardening element) are possible. Previously restricted to about 2.0%, titanium can be increased to 3.5%, the limit of solid solubility, and the alloy will still retain enough ductility. At these higher titanium levels, the material is much stronger and has a longer creep-rupture life at the same stress. The nominal chemical compositions of Discaloy and W-545 are as follows:

	Discaloy	W-545
Nickel	26	26
Chromium	13	13
Molybdenum	3.0	1.5
Titanium	1.8	2.8
Boron	—	0.03
Iron	Bal.	Bal.

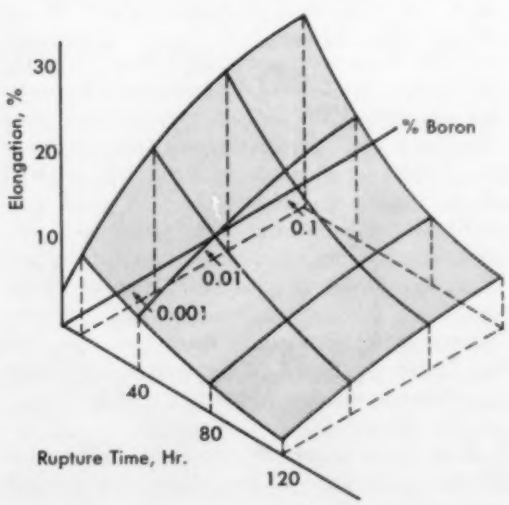
More than 50 experimental heats were forged to bar stock and test specimens machined from the heat treated stock. Examination of the stress-rupture properties obtained by testing specimens with a constant A.S.T.M. grain size No. 4 to 5 indicated that as the titanium content was increased, the boron content also had to be increased to obtain the full boron effect. At a titanium level of about 1.7%, a boron content of 0.005% was quite sufficient to obtain the boron effect; increases above 0.007% did not affect the properties. For a titanium content around 2.4%, about 0.02% B was needed to obtain sufficient rupture ductility. To investigate the boron effect more fully, a number of alloy combinations were produced and the results obtained are delineated in the three-dimensional plot of boron content versus rupture time and rupture elongation (Fig. 1). The surface represented in the graph is characterized by a decreasing rupture elongation with increasing rupture time and increasing rupture elongation with increasing boron content.

Notch Sensitivity

The subject of notch sensitivity was mentioned previously. We feel that for true notch ductility a notched bar must have a greater rupture life *at constant stress* than the comparable unnotched bar. Experiments were therefore conducted to investigate the effect of increasing amounts of boron on notch sensitivity. These were stress-rupture tests of several similar heats of the same chemical composition (2.4% Ti level) which varied only in boron content. A notch concentration ratio of 3.9 was used on all of these specimens.

The tests were conducted at 1200° F. and 70,000 psi. on heats varying from 0 to 0.12% B. Two widely different types of aging treatments were used to evaluate the effect of heat treatment. They were: (*a*) heated for 20 hr. at 1350°

Fig. 1 – Generalized Effect of Boron on the Ductility at Different Rupture Times of W-545 Type Alloys at 1200° F. and 70,000 Psi.



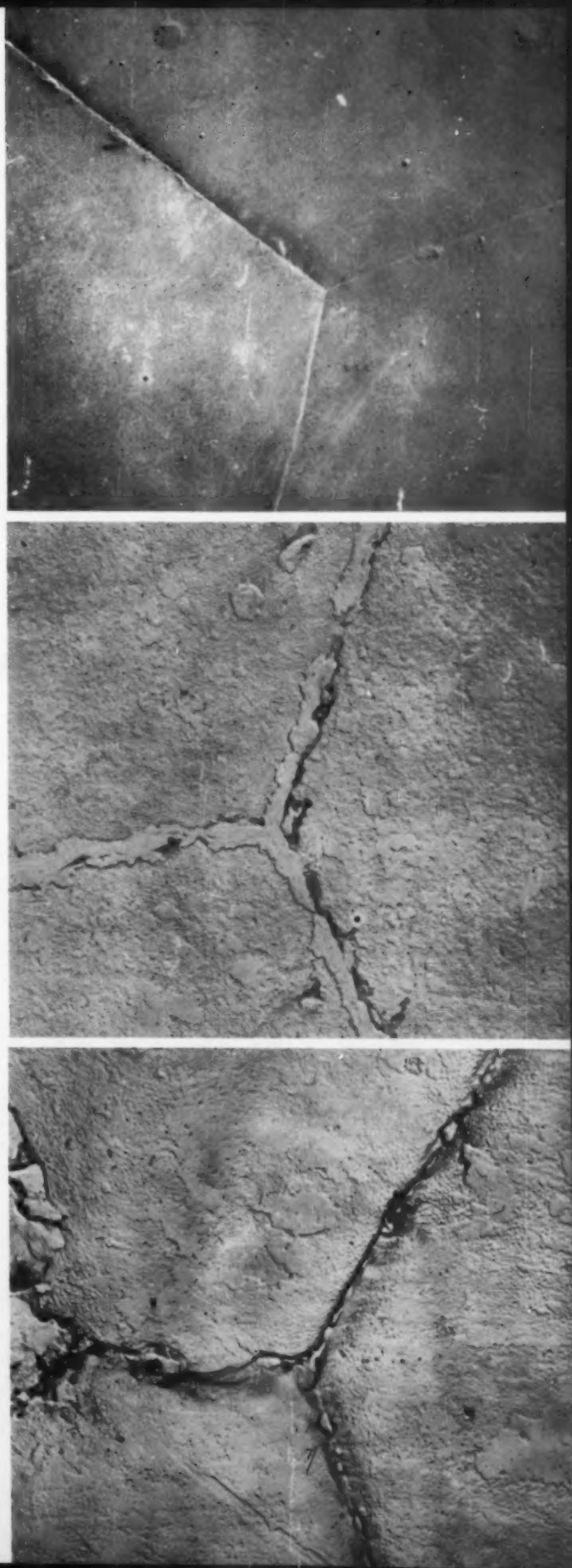


Fig. 2 – Electron Photomicrographs of Precipitation Hardening Alloys in Three Conditions. The first shows solution treated W-545; the second reveals continuous grain boundaries in an aged alloy without boron; and the third shows aged W-545. Note the discontinuous grain boundary in the last photograph. All pictures 10,000 × (reduced for reproduction)

F., cooled to 1200° F., and held 20 hr. at 1200° F.; and (*b*) heated for 16 hr. at 1200° F., raised in 16 hr. to 1300° F., and held for an additional 12 hr. The latter treatment we call "Genuage."

Results of the creep-rupture tests are shown in Table I. We see that as the boron content increases, the unnotched rupture ductility increases; at approximately 5% elongation, the notched rupture times become longer than the unnotched rupture times.

Heat treatments and aging treatments are very potent methods for controlling the stress-rupture properties of precipitation hardening alloys. Strength and ductility controlling factors in these alloys are believed to be the size and distribution of the precipitated phase whether it be coherent or non-coherent.

Theory of the Boron Effect

It is generally conceded that boron makes an alloy stronger or more ductile – sometimes, both. (It must be remembered that stress-rupture strengthening should be defined as lowering of the minimum creep rate as well as increasing the rupture time.) Most of the ideas are theoretically sound; there may be, therefore, more than one boron effect.

Most theories are hinged on the location and the unusual size of the boron atom. It is about three-fourths the size of the usual substitutional elements (iron, chromium, cobalt, nickel, manganese and vanadium), but somewhat larger than the interstitials (hydrogen, carbon and nitrogen). Thus, it cannot be conveniently either a substitutional or interstitial element: Boron could therefore strengthen an alloy by being forced into either position. If forced into an interstitial position, the other atoms would be spread apart, introducing internal stresses. Conversely, if located in a substitutional position, the neighboring atoms would contract around the boron atom and also introduce internal stresses.

Boron can make an alloy more ductile by assuming a concentration mechanism to be present. The most logical location for such a concentration is the grain boundaries. These are sites of

localized natural lattice imperfections due to the difference in orientation between neighboring grains. Holes of varying size occur (depending on the orientation difference between neighboring grains) which could accommodate boron atoms. If located in the grain boundaries, boron atoms would slow down the precipitation reaction at the grain boundaries. For precipitation to occur, atoms of the approximate stoichiometric composition of the precipitate must come together by diffusion. Since boundaries are short-circuit diffusional paths, boron atoms in the boundaries would block diffusion and might cause a disruption of the normal precipitation reaction. Normally, a continuous grain-boundary precipitate might be expected to form; a generalized within-the-grain precipitate occurs only after boundary precipitation is nearly complete. A continuous grain-boundary precipitate is bad for stress-rupture ductility since metals commonly fracture at high temperatures through the grain boundaries, and a brittle boundary precipitate often leads to a brittle fracture.

Table II – Properties of Commercial Wrought Products of W-545

Mechanical Properties

Yield Strength	Ultimate Strength	Elongation	Reduction of Area	Hardness
(a) 116,000 psi.	151,000 psi.	18%	21%	C-31 to 32
(b) 129,000	162,000	12	14	35 to 36
(c) 108,000	142,000	8	—	32
(d) 115,000	162,000	20	25	35

Stress-Rupture Data

Temperature	Stress	Unnotched Rupture Time	Elongation	Notched Rupture Time
(a) 1200° F.	70,000 psi.	33 hr.	12.4%	58 hr.
1200	70,000	40	11.3	76
1200	70,000	100	6.6	774
(b) 1200	75,000	25	10.0	364
1300	60,000	143	5.2	384
1300	65,000	31	5.4	105
1300	70,000	6.1	11.7	67
(c) 1200	75,000	41	—	—
1300	60,000	25	—	—
(d) 1200	80,000	25	18	—
1200	75,000	143	12	—

(a) Bar stock, 2.4% Ti.
(b) Pancake disk forgings, 2.7% Ti.
(c) Sheet stock, 2.7% Ti.
(d) Disk forgings (consumable electrode vacuum arc melted ingot), 2.8% Ti.

With boron atoms in the boundaries, one might expect a breaking-up of the continuous grain-boundary precipitate along with a generalized precipitate. Figure 2 illustrates electron photomicrographs of three W-545 type microstructures. The first shows the junction of three grains in the solution-treated condition, typical of the alloy both with and without boron. When the alloy without boron is precipitation hardened, a continuous grain-boundary precipitate occurs as does a within-the-grain precipitate. This is pictured by the second photograph. The probability of getting much ductility from such an alloy by grain-boundary sliding or within-the-grain slip seems rather remote. The age hardened boron-containing alloy has a discontinuous grain-boundary precipitate as well as generalized precipitate within the grains. Grain-boundary sliding and some slip within the grains would seem quite likely; specimens with the structure shown in the last picture were ductile. If the boundary precipitate and the within-the-grain precipitate are different compounds (for example, the former a carbide phase and the latter an Ni_3Al or Fe_2Ti type), there exists another possibility for a boron effect. Boron then may modify the carbide phase which forms at the boundaries to either a boro-carbide or carboboride; these would not be as likely to grow into a cellular or lamellar shape as is commonly observed with carbide phases. Cellular-shaped precipitates have been shown to have a deleterious effect on properties in some alloys.

Production of this new alloy has passed beyond the laboratory stage in that properties of wrought products made from commercial-size ingots are similar to those of wrought bar stock produced in the laboratory. Wrought products from the 1000 to 5000-lb. commercial ingots made thus far are bar stock, sheet stock, and pancake and contour-forged turbine disks. Some typical mechanical properties obtained from these products are listed in Table II. These data illustrate that the commercial development of the new alloy has fulfilled the best hopes of the designers.

Swedes Make Modern Bearings

*By A. E. OLSSON**

Electrolytic salt bath cleaning and centrifugal casting together can produce strong, long-lived bearings.. A well-known European manufacturer of heavy equipment is having great success with this combination.
(T7d, L12n, S14; CI, Sn, *Pb*)

IN THE RUSH of modern technology, every country is making its contribution. We in Sweden have done our part in a number of fields, notably in sponge iron and rotary-hearth steelmaking. Other areas have received our attention, too. The manufacture of turbines and heavy railroad equipment has concerned us for years, and in these items strong and durable bearings are a must.

The bearing quality, in fact, largely determines operating life and maintenance cost of the equipment. To achieve this, we resort to both electrolytic salt-bath cleaning and centrifugal casting; together, they insure a well-bonded, thin babbitt coat essential in the production of a good bearing.

Figure 1 illustrates the Kolene No. 4 salt-bath unit which cleans all surfaces thoroughly. The bearing shells travel in a cradle (suspended from an overhead hoist) through a sliding door and settle into the bath which acts as an electrolyte in a direct-current cell. One pole is the load, the other the salt pot. When the load is made positive (this is the first step), graphitic carbon oxidizes to carbon dioxide (which reacts to form sodium carbonate) and ferrous oxide to ferric oxide. Other elements – silicon, phosphorus, and sulphur among them – also oxidize. Polarity is then reversed, and reducing reactions occur which remove the oxides previously formed.

*Production Manager, Nydqvist & Holm Aktiebolag, Trollhätten, Sweden.

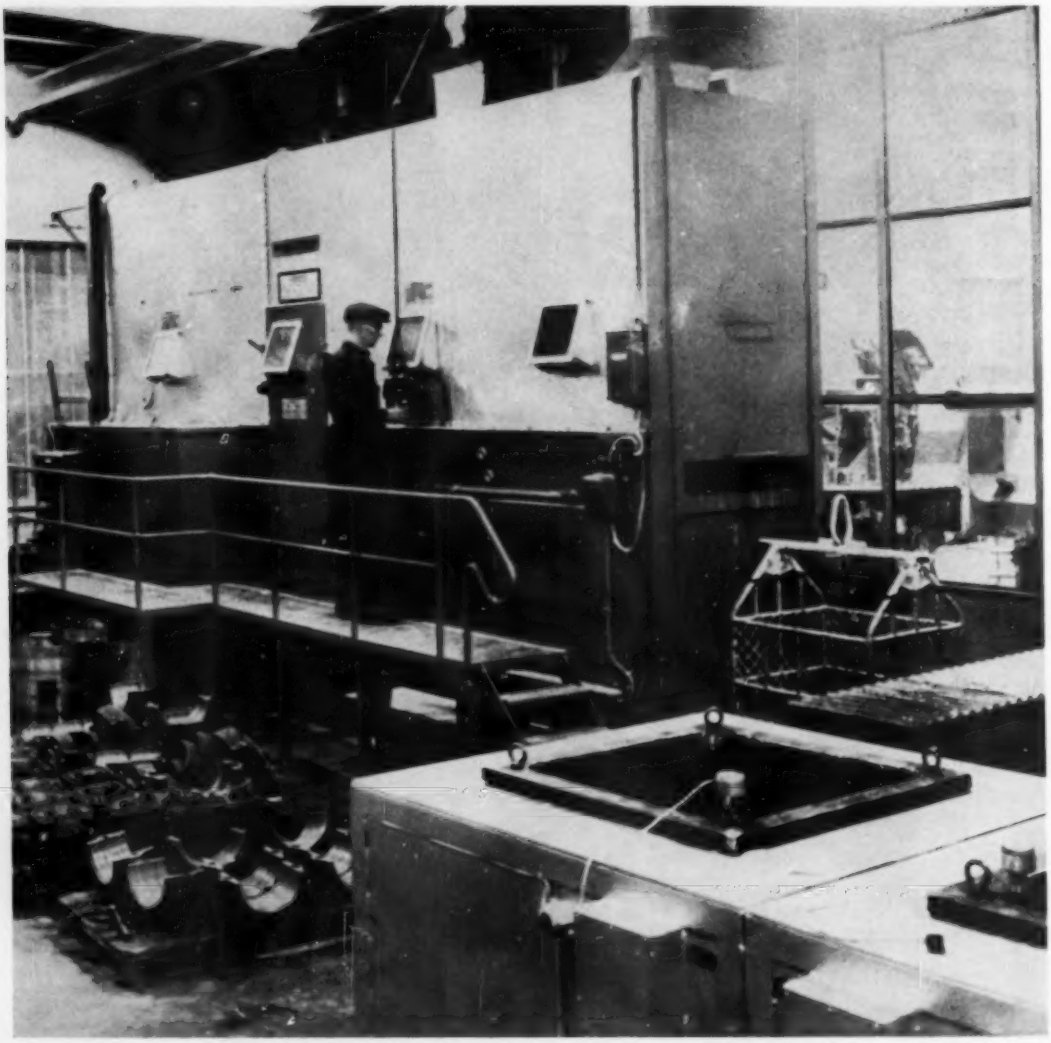


Fig. 1 — The Electrolytic Salt-Bath Cleaning Unit Shown Here Uses Kolene No. 4 Salt. A cooling zone and two rinse baths are also under the hood; the whole setup is ventilated by a large fan (not shown). The roller table and the tinning baths are in the foreground

Sand, rust, and scale are also eliminated. In some large bearing shells (around 6 in. ID), an oxidation period of 15 min. followed by a reduction period of 20 min. is repeated three times. For smaller bearings — they may have inside diameters as small as 1½ in. — the cleaning time is obviously shorter.

When the work is clean, it is allowed to hang in the adjacent cooling area to drip for a short time, and is then immersed in a room-temperature water rinse kept clean by overflowing. The final rinse takes place in a heated water tank. Since the work is still warm (about 180° F.), drying is rapid, and the bearing is ready to be tinned.

Babbitting the Bearing

When the bearing leaves the cleaning unit, it moves to an adjacent roller table. There, areas not to be tinned are painted with a quick-drying mixture of magnesia and water-glass. This coating can withstand acids, fluxes, and temperatures up to 570° F. Successive dippings into an aqueous 10% HCl solution and a zinc ammonium chloride flux follow the coating operation; after this, the bearing shell is completely tinned in two baths containing a 60:40 tin-lead mixture. A dry flux, applied while the tinning coat is still molten (about 520° F.), removes any oxide present.

The bearing is now ready to be babbitted. While still around 500° F., it enters a centrifugal casting machine whose speed is varied according to the size of the bearing. (Other refinements of the machine include gas-heated end plates which are preheated before enclosing the bearing, and a water inlet for rapid cooling.) When the bearing reaches the proper speed, the proper amount of babbitt is ladled into it; this flows over the surface in a thin, even coating. Quenching follows. The bearing is ready for use when the inside diameter is machined and the ends are faced.

Properties and Structure

One major requirement for a long-lasting bearing is a thin coat of babbitt, as mentioned before. When the babbitt layer is thin enough, the backing withstands the load while the babbitt supplies only the lubrication. The graph of Fig. 2 shows that as the thickness drops from 0.012 in. to 0.001 in., bearing life rises from 50 to 300 hr.

Another essential need for an adequate babbitt coating is a good bond. This method produces bonds of excellent character, as Fig. 3 illustrates. Since the surface of the cast iron backing has been so thoroughly cleaned (even to removal of the surface graphite), the babbitt, with the aid of centrifugal force, can achieve a very firm union. The photomicrograph shows how well this has been done. It is apparent that the tinning mixture, which aids the bonding of babbitt to cast iron, flowed into every crevice in the surface. The thin, uniform layer of babbitt completes the bearing.

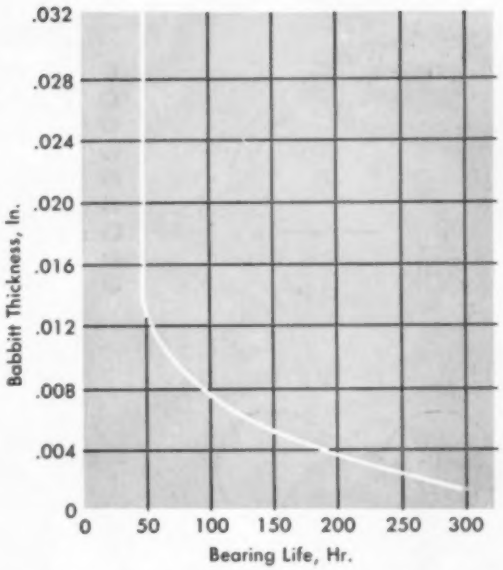
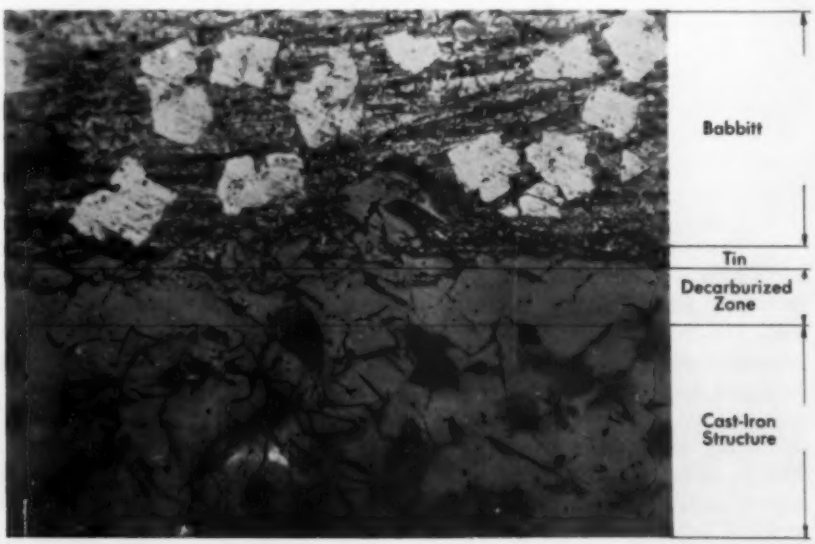


Fig. 2 – Improvement in Bearing Life as Coat Thickness Is Lessened. Maximum unit load is 1330 psi.

Thus, the modern techniques of electrolytic salt-bath cleaning and centrifugal casting can be combined to produce quality bearings. This equipment has now been in operation for over a year, and results have been highly satisfactory.

Fig. 3 – Babbitt-Cast Iron Interface. Note excellent bond achieved by the process. The horizontal lines enclose the zone from which graphite was removed by the cleaning operation (the tinning alloy is now present there)



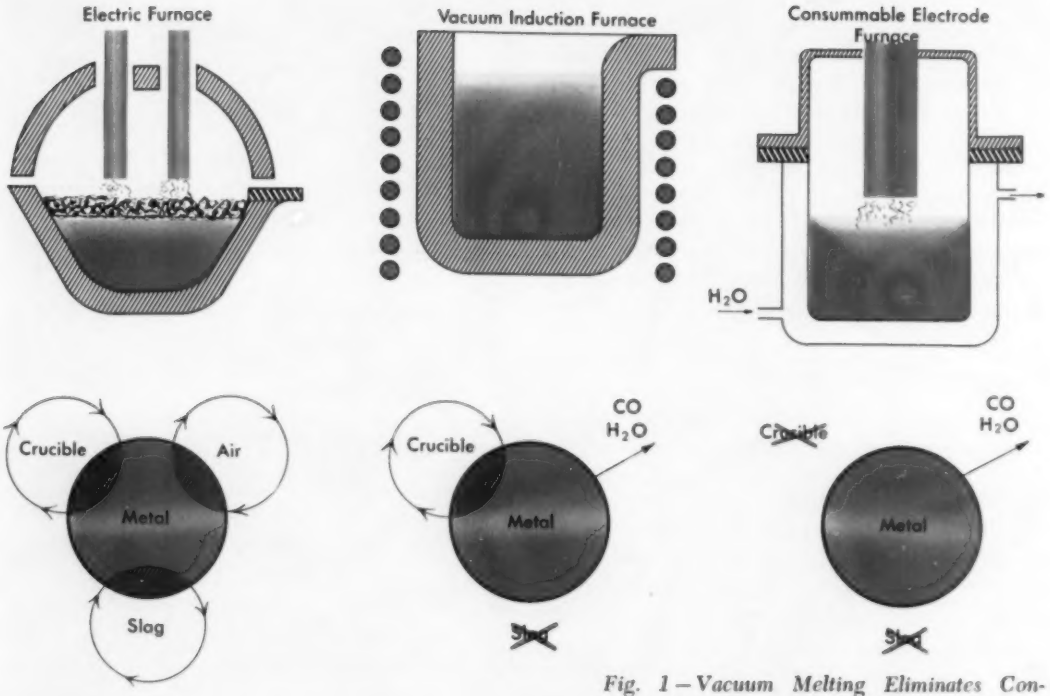


Fig. 1 — Vacuum Melting Eliminates Contamination Source. Only the crucible can contaminate induction-melted alloys and this is eliminated by consumable arc remelting

Staff Report

Vacuum Melting Today

WHEN WE CONSIDER that only a few years ago vacuum melting was little more than a laboratory curiosity, its progress has been phenomenal. The engineering advantages of vacuum-processed metals are being recognized and the increased demand is creating the need for larger melting equipment. Heats of 2000 to 3000 lb. are being induction melted regularly; a new 5000-lb. induction melting furnace (the world's largest) will start operating soon. Vacuum arc remelted ingots in excess of 12,000 lb. are available and larger sizes are in the offing. If larger ingots of vacuum treated metal are needed, the degassing method offers them up to 250 tons. New producers are entering the vacuum field and experienced melters are adding alloys.

Why this sudden interest in melting metals without an atmosphere? The answer lies in the increasing stringency of many military and industrial requirements. Turbine buckets must operate for a reasonable length of time in the 1500 to 1800° F. range. New superalloys are being

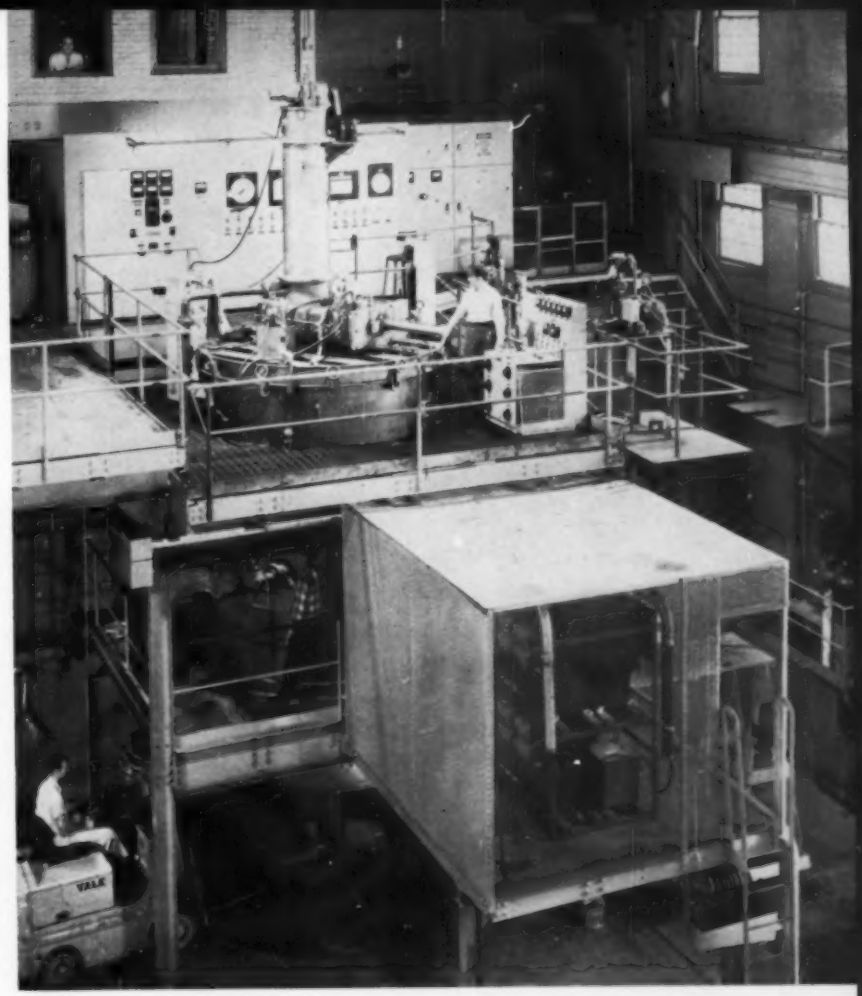


Fig. 2—A Typical Induction Melting Installation. Charging, melting, and pouring all take place in a high vacuum. (Courtesy Universal-Cyclops Steel Corp.)

developed for improved hot strength which can be melted only in a vacuum.

The need for metals with higher strength-to-weight ratio, for aircraft especially, is resulting in increased use of ultra high-strength steels. In heat treating for increased strength, ductility drops particularly in the center because of segregation. Vacuum processes aid center ductility appreciably. Vacuum-melted alloys used in bearing applications give long life under the most difficult operating conditions. Vacuum-poured steel holds great promise for the solution of problems in the manufacture of large forgings. These are a few areas in which vacuum methods can make a better product. Many others exist; suppliers prove this by developing more alloys all the time. The data sheet on p. 96-B gives the commercial alloys now available from the various producers.

Vacuum is being increasingly used in processing steels and superalloys for today's most stringent applications. Appreciable amounts of active elements can be added as alloying agents; gases and inclusions are reduced. The user has available a number of vacuum-produced alloys and more are in the offing. (C25, C5, Dg, 1-73)

Production Methods

Three are in commercial use: (*a*) vacuum induction melting, (*b*) consumable electrode remelting, and (*c*) degassing. Each process has its advantages and disadvantages; all, however, produce metals of greater purity than conventional air melting. In vacuum induction melting, all production from charge to tap is carried out under a vacuum. In consumable electrode remelting, the alloy is remelted and recast under a

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Materials are the common denominator of all engineering and in this age of fast-moving changes the need for efficient selection of materials is greater than ever before.

The articles and data sheet which follow on vacuum melted alloys constitute the first in a series of special reports on metallic materials which the editors of *Metal Progress* will present from time to time to help you do a better job in metals engineering.

Fig. 3 – Vacuum Degassing Unit. Hydrogen in air-melted steel is reduced considerably by this process. (Courtesy United States Steel Corp.)

vacuum. In degassing, pouring only is performed under a vacuum. The ability of vacuum processes to reduce inclusions and gases is definite. Sources for inclusions are eliminated by use of the two vacuum processes as illustrated by Fig. 1, while Table I shows reductions in gas content.

Vacuum induction melting takes place in an induction furnace situated in a vacuum chamber. Charging, melting, and pouring are done at about 5 microns, although pressures often vary during the melt. A typical arrangement is illustrated in Fig. 2; other installations may include a separate chamber for molds so that semicontinuous operation is possible. Under these conditions, melters report operation for as long as a week without breaking the furnace seal.

Table I – Average Gas Contents of Production Heats*

Grade	Type of Melting	O_2	N_2	H_2
A-286	Air melt electrode	13.0	300.0	13.1
	Vacuum arc remelt	5.0	20.0	2.8
	Vacuum induction	3.0	50.0	2.3
Waspaloy	Air melt electrode	31.0	420.0	17.7
	Vacuum arc remelt	2.0	120.0	2.2
	Vacuum induction	12.0	120.0	2.5
M-252	Air melt electrode	15.0	160.0	16.0
	Vacuum arc remelt	6.0	40.0	1.7
	Vacuum induction	5.0	30.0	1.5

*Data (parts per million) supplied by E. A. Loria, Staff Metallurgist, Crucible Steel Co. of America, Pittsburgh.

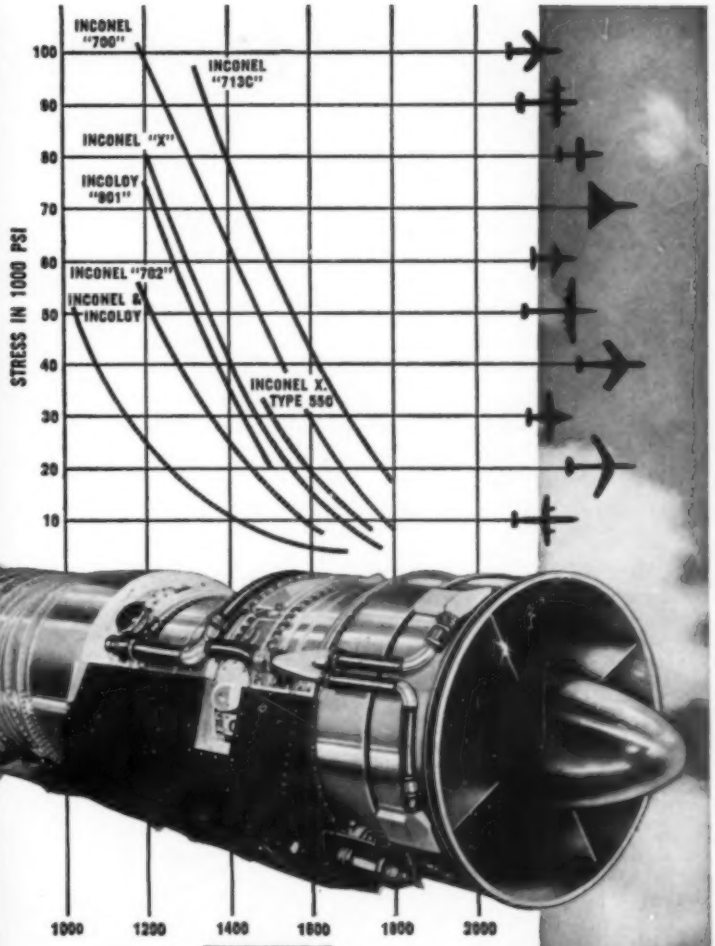
A typical melt might go something like this. Carefully selected scrap and virtually pure metals (for alloy additions) compose the charge. It is put into a hopper whose chamber is then evacuated as is the furnace chamber. The charge drops into the crucible, following which the leak rate is determined by closing the valves to the pumps and checking the pressure rise. A rise of 5 microns per min. is a typical limit. Although most alloy additions are made with the initial charge, a few (manganese, which has a high vapor pressure, is the most notable example) have to be added when the melt is nearly ready to tap.

This is also true of titanium and aluminum; they are both highly reactive and combine readily with any oxygen or nitrogen present. Under these conditions, the leak rate is obviously important. Today's vacuum pumps can maintain a 1-micron pressure when as much as 100 microns per min. leak rate is present. When all additions are made, the temperature is determined (by an optical pyrometer generally, though an immersion thermocouple is often used for a check) and the heat is poured into molds which are also under a vacuum.

Since gases (other than those, such as carbon dioxide, emerging from the melt) are absent throughout the production cycle, deoxidizers such as manganese and silicon are not needed. This is fortunate because both are detrimental to high-temperature mechanical properties. The only source of contamination is the crucible (crucible attack, incidentally, is the main problem in the induction process); it is usually made

new Inco alloys

give excellent performance in high stress, high temperature, aeronautical applications



100 HR CREEP RUPTURE STRENGTH OF SOME INCO ALLOYS

Aircraft engineers will recognize this gas turbine engine . . . the new Orenda "Iroquois". Some of the Inco alloys employed in the "Iroquois" are depicted on the graph above. This graph shows maximum temperatures which these and other Inco alloys will withstand for 100-hour life at various stresses.

Naturally, the selection of materials for high temperature applications involves many other factors not illustrated in this graph. Where stress is low, for example, higher temperatures may be permissible. Much of this technical information has already been accumulated by Inco.

New wrought alloys such as Inconel 700* and Incoloy 901*, developed by Inco, are available for high temperature service. A precision casting alloy — Inconel 713C* — has recently been added to the group. Alloys that resist oxidation at temperatures up to and beyond 2000°F. have been perfected.

Modern high speed flight has cleared the sound barrier and is penetrating the thermal thicket. Advanced turbo-jets, rockets and ramjets are producing unbelievable levels of power. As power and speed increase, temperatures become more critical. Inco's research and production facilities are dedicated to the task of keeping abreast of these developments.

For information concerning special Inco alloys for high temperature applications, write today.

*Registered trademark

INCO

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street, New York 5, N. Y.

Nickel-Base Superalloys

Grade	Source—See Key	Nominal Compositions	Remarks
Udimet 500	(1), (2), (3), (4)‡, (5), (8), (11), (13), (15)§	C 0.10; Cr 19.0; Mo 4.0; Ti 3.0; Al 3.0; Co 19.0; Ni bal.	Jet engine buckets, disks, bolts, and rotors. High-temperature sheet.
Udimet 600	(5), (8)	C 0.10; Cr 18.0; Mo 4.0; Ti 3.0; Al 4.0; B 0.40 max.; Co 18.0; Ni bal.	Jet engine parts.
Udimet 700	(5), (8)	C 0.15; Cr 17.0; Mo 4.0; Ti 4.0; Al 4.0; B 1.0 max.; Co 18.0; Ni bal.	Jet engine parts.
M-252	(1)*, (2), (3), (4)‡*, (5), (6), (8), (11), (12), (13), (16)†	C 0.15; Cr 19.0; Mo 9.75; Co 10.0; Al 1.10; Ti 2.50; Fe 1.25; Zr 0.06; B 0.005; Ni bal.	Jet engine parts.
Waspaloy	(1)‡*, (2), (4)‡*, (5), (6), (8), (11), (12), (13), (15)§, (16)†	C 0.08; Cr 19.5; Mo 4.3; Co 13.5; Al 1.3; Ti 3.1; Fe 1.25; Ni bal.	Turbojet blades and rotor disks.
Inco 700	(4), (8), (16)†	C 0.14; Cr 16.0; Mo 3.0; Co 30.0; Al 3.1; Ti 2.35; Fe 1.5; B 0.005; Zr 0.05; Ni bal.	Jet engine buckets, disks, bolts.
Inconel 713 C	(8), (17)	Cr 12.0; Mo 4.5; Cb 2.0; Al 6.0; Ti 0.5; Ni bal.	Jet engine blades.
Incoloy 901	(1)†, (4)*, (8), (9)†, (11), (12), (17)†	C 0.04; Cr 13.0; Ti 2.4; Ni 42.0; Mo 6.0; Fe bal.	Turbine wheels, rims, and shafts.
GMR 235	(2), (3), (4)‡, (6), (8)	C 0.15; Cr 16.0; Mo 5.3; Al 3.2; Ti 2.2; Fe 10.0; B 0.075; Ni bal.	High-temperature areas in jet engines.
GMR 235 D	(3), (4)‡, (8)	C 0.15; Cr 15.5; Mo 5.25; Al 3.6; Ti 2.5; Fe 4.25; B 0.075; Ni bal.	Cast variety of GMR 235.
Hastelloy Alloy R-235	(3), (4)‡, (6), (8), (11)	C 0.16; Cr 15.5; Mo 5.5; Al 2.0; Ti 2.5; Fe 10.0; Ni bal.	Jet afterburners, blading, etc.
Hastelloy Alloy F	(3)	C 0.02; Cr 22.0; Mo 6.5; Cb+Ta 2.2 (Ta 0.50 min.); Ni 45.5; Fe bal.	Sulphite pulp digestors for paper.
Hastelloy Alloy X	(3), (4)*, (11)	C 0.15; Cr 22.0; C 1.5; Mo 9.0; W 0.6; Ni 45.0; Fe bal.	Flange rings in hot end of jet engines.
D 979	(1)†	C 0.07; Cr 14.3; Mo 3.8; W 3.9; Al 1.1; Ti 3.9; B 0.01; Ni 45.0; Fe bal.	High-temperature alloy; good hot workability.
DCM	(2), (3), (5)	C 0.05; Cr 14.3; Mo 5.3; Fe 4.6; Al 4.3; Ti 3.4; B 0.08; Fe bal.	Turbine blades (G.E. alloy—not commercially available).
Nicrotung	(11), (15)	C 0.10; Cr 12.0; Co 10.0; W 8.0; Al 4.0; Ti 4.0; B 0.05; Zr 0.02; Ni bal.	Castings for high-temperature service.
René 41	(1), (2), (3), (4)‡, (5), (6), (8), (11), (13)	C 0.09; Cr 19.0; Ni 52.5; Mo 9.75; Co 11.0; Al 1.65; Ti 3.15; B 0.005	Jet engine parts and sheet.
Nimonic 80 A	(4)*, (6)	C 0.04; Cr 20.5; Al 1.2; Ti 2.4; Ni bal.	Jet engine parts.
Nimonic 90	(4)*, (6)	C 0.08; Cr 19.0; Co 20.0; Al 1.7; Ti 2.7; Ni bal.	Jet engine parts.
Refractaloy 26	(4)*, (15)†	C 0.03; Cr 18.0; Ni 38.0; Mo 3.2; Co 20.0; Al 0.2; Ti 2.6; Fe bal.	Jet engine parts.
K-42-B	(4)*, (12), (15)†	C 0.03; Cr 18.0; Ni 42.0; Co 22.0; Al 0.20; Ti 2.1; Fe bal.	Low coefficient of thermal expansion.

Iron-Base Superalloys

A-286	(1)†, (4)*, (6), (7), (8), (9)†, (10)†, (11)‡, (12), (13)†, (14)†, (16)†	C 0.06; Cr 14.8; Ni 25.5; Mo 1.3; V 0.3; Ti 2.0; B 0.003; Fe bal.	Jet engine wheels and cases.
Discaloy	(1)†, (4)*, (9)†, (10)†, (11), (15)†, (16)†	C 0.06; Cr 13.5; Ni 26.0; Mo 3.0; Ti 1.7; Fe bal.	Turbojet wheels.
W-545	(9)†, (10)†, (15)†	C 0.05; Cr 13.5; Ni 26.0; Mo 1.5; Al 0.20; Ti 2.85; B 0.06; Fe bal.	Jet engine parts.
Unitemp 212	(4)‡*	C 0.08; Cr 16.0; Ni 25.0; Cb 0.50; Ti 4.0; Al 0.35; B 0.07; Zr 0.05; Fe bal.	Jet engine parts.
M-308	(1)‡, (2), (4)‡, (5), (6), (11)‡, (12), (13), (16)†	C 0.08; Cr 14.0; Ni 33.0; Mo 4.0; Al 0.25; Zr 0.25; Ti 2.0; W 6.5; Fe bal.	Jet engine parts.
Ferrovac 42% Ni	(6)	Ni 42.0; Fe 58.0	Magnetic alloy.

Alloy Toolsteels

AISI A-2	(1)*, (4)*, (5), (6), (7), (10)†, (12), (14)*	C 1.0; Cr 5.0; Mo 1.0; Fe bal.	Gages and rolls.
AISI D-2	(1)*, (2), (4)*, (5), (6), (7), (9)†, (12), (14)*	C 1.5; Cr 12.0; Mo 1.0; Fe bal.	Dies, gages, and jewelry rolls (sometimes modified by vanadium).
AISI D-4	(1)*, (2), (5), (6), (7), (9)†, (14)*	C 2.2; Cr 12.0; Mo 1.0; Fe bal.	Greater wear resistance than D-2.
AISI H-11	(1)*, (2), (4)*, (5), (7), (10)†, (12), (13)†, (14)*	C 0.35; Cr 5.0; Mo 1.5; V 0.40; Fe bal.	Dies, gages, and rolls (with 1.0 Si, suitable for strong structural parts at high temperature).
AISI H-13	(1)*, (7), (10), (12), (14)*	C 0.35; Cr 5.0; Mo 1.5; V 1.00; Fe bal.	
AISI M-1	(1)*, (2), (4)*, (5), (6), (7), (9),† (10)†, (12), (14)*	C 0.80; Cr 4.0; Mo 8.0; V 1.0; W 1.5; Fe bal.	Toolsteel for high-temperature bearings.
AISI M-2	(1)*, (2), (4)*, (5), (6), (7), (9)†, (10)†, (12), (14)*	C 0.85; Cr 4.0; Mo 5.0; V 2.0; W 6.0; Fe bal.	High speed steel.
AISI M-10	(1)*, (2), (4)*, (5), (6), (7), (9)†, (10)†, (14)*	C 0.85; Cr 4.0; Mo 8.0; V 2.0; Fe bal.	High speed toolsteel (bearings, taps, drills).
AISI M-50	(1)*, (2), (4)*, (5), (6), (7), (9)†, (10)†, (14)*	C 0.80; Cr 4.0; Mo 4.25; V 1.0; Fe bal.	Bearings, hot work die steels.
AISI T-1	(1)*, (4)*, (5), (6), (7), (9)†, (14)*	C 0.70; Cr 4.0; V 1.0; W 18.0; Fe bal.	Toolsteel for high-temperature bearings.
AISI T-15	(1)*, (2), (4)*, (5), (7), (14)*,	C 1.55; Cr 4.0; V 5.0; W 12.0; Co 5.0; Fe bal.	High-temperature bearings.
Rex Super Cut	(6)	C 0.80; Cr 4.0; Mo 0.60; V 2.0; W 18.5; Co 8.0	T-5 toolsteel with molybdenum; high-temperature bearings.

Melted Alloys

Cobalt-Base Superalloys

Grade	Source—See Key	Nominal Compositions	Remarks
GE 1570	(2), (3), (4)‡, (5), (6), (11)	C 0.18; Cr 20.0; Ni 29.0; W 7.3; Ti 4.3; Fe 1.4; Co 37.5	High-temperature areas in heat engines.
X-40	(2), (3), (7), (8), (11)	Cr 23.0; Ni 10.0; W 7.0; Co bal.	High-temperature areas in jet engines
S-816	(1)*, (4)*, (5), (6)	Cr 20.0; Ni 20.0; Mo 4.0; Cb+Ta 4.0; W 4.0; Mn 1.5; Co bal.	High-temperature alloy.
J-1650	(2)	C 0.20; Cr 19.0; Ni 27.0; W 12.0; Ta 2.0; Ti 3.8; B 0.02; Co bal.	Jet engine parts.

Stainless and Heat Resisting Steels

Greek Ascoloy	(1)*, (4)*, (7), (10)†, (11), (14)*	C 0.18; Cr 12.5; Ni 2.0; W 2.75; Fe bal.	High-temperature alloy.
Turbine Alloy	(7), (9)†, (10)†	C 0.20; Cr 13.0; Ni 0.75; Mo 1.0; V 0.40; W 1.00; Fe bal.	High-temperature alloy.
Armco 17-4 PH	(8), (9)†	C 0.07; Cr 16.5; Ni 4.0; Cu 4.0; Cb 0.35; Fe bal.	Strong, corrosion resistant alloy.
AISI Type 304	(6)	C 0.08 max; Cr 19.0; Ni 10.0; Fe bal.	Electronic tubes.
AISI Type 310	(1)*, (4)*, (5), (7), (8), (9)†, (10)†	C 0.25 max; Cr 25.0; Ni 20.5; Fe bal.	Corrosion resistance.
AISI Type 316	(1)*, (4)*, (5), (7), (9)†, (10)†, (11)	Cr 17.0; Ni 12.0; Mo 2.5	Corrosion resistance.
AISI Type 347	(1)*, (2), (4)*, (5), (6), (7), (9)†, (10)†, (11)	C 0.08; Cr 18.0; Ni 9.9; Mn 1.9; Cb+Ta 0.9; Fe bal.	Core wire for welding; jet engine parts
AISI Type 403	(1)*, (4)*, (5), (7), (8), (9)†, (10)†, (12), (14)*	C 0.15 max; Cr 12.5; Si 0.50 max; Fe bal.	Steam and gas turbine parts.
AISI Type 410	(1)*, (4)*, (5), (7), (8), (9)†, (10)†, (14)*	C 0.15 max; Cr 12.5; Si 1.0 max; Fe bal.	Cast version of Type 403.
AISI Type 430	(9)†	C 0.12 max; Cr 16.0; Fe bal.	Ferritic stainless steel.
AISI Type 431	(1)†, (4)*, (5), (7), (9)†, (10)†, (12)	C 0.20 max; Cr 16.0; Ni 1.8; Fe bal.	Corrosion resistance.
AISI Type 440C	(1)*, (2), (4)*, (5), (6), (7), (10)†, (14)*	C 1.05; Cr 17.0; Mo 0.50; Fe bal.	Instrument bearings and high-strength rolls.
18-8 B	(4), (6)	C 0.06; Cr 19.0; Ni 9.5; B 2.15; Fe bal.	Atomic energy applications (neutron control rods).
18-15 B	(4), (11)	C 0.01; Cr 18.0; Ni 15.0; B 0.80; Fe bal.	Same as above.
Lapelloy	(1)†, (4)*, (7), (10)†, (11), (12), (14)*	C 0.30; Cr 11.5; Mo 2.75; V 0.25; Fe bal.	Gas turbine parts.
Lapelloy C	(12)	C 0.25; Cr 11.5; Mo 2.75; Co 2.0; N 0.08; Fe bal.	Same as above.

Miscellaneous Steels

AISI 4340	(1)*, (2), (4)*, (5), (6), (7), (9)†, (10)†, (12), (14)*, (15)*, (16)†	C 0.40; Cr 0.80; Ni 1.8; Mo 0.25; Fe bal.	Ultra high-strength structural parts.
AISI 6150	(1)*, (2), (4)*, (5), (6), (7), (9)†, (10)†, (12), (14)*	C 0.50; Cr 1.00; V 0.20; Fe bal.	Aircraft valve springs, fasteners.
AISI 9310	(1)†, (2), (4)*, (5), (6), (7), (9)†, (10)†, (14)*	C 0.10; Cr 1.2; Ni 3.2; Mo 0.12; Fe bal.	Gear alloy.
AISI 9317	(1)†, (4)*, (6), (7), (10)†, (14)*	C 0.16; Cr 1.2; Ni 3.2; Mo 0.12; Fe bal.	High-strength steel.
Inco UHS Steel	(1), (6)	C 0.43; Cr 0.8; Ni 1.8; Mo 0.37; Si 1.65; V 0.05 min.	Aircraft landing gears.
AISI 51100	(1)*, (2), (4)*, (5), (6), (7), (9)†, (10)†, (12), (14)*	C 1.00; Cr 1.00; Fe bal.	Bearing steel.
AISI 52100	(1)*, (2), (4)*, (5), (6), (7), (9)†, (10)†, (12), (14)*, (15)*, (16)†	C 1.00; Cr 1.50; Fe bal.	Bearing steel.
Alnico 5	(11)	Al 8.0; Ni 14.0; Co 24.0; Fe bal.	Cast permanent magnets.
Hipermik	(6), (11), (12), (15)	Ni 50.0; Fe 50.0.	High-permeability, low-coercive force alloy.
Magnetic Alloy	(8), (11), (14)*	C 0.75; Cr 4.0; Co 0.40; W 5.0; Fe bal.	Castings and wrought forms for magnetic uses.
Thermenol	(3), (4), (6), (11), (15)	C 0.03; Mo 3.3; Al 15.4; Fe bal.	Magnetic and heat resistant uses.
Alfenol	(4), (6), (11), (12), (15)	C 0.01; Al 15.8; Fe bal.	Magnetic and heat resistant uses.
Alfenol 12	(12)	C 0.01; Al 12.0; Fe bal.	Magnetic and heat resistant uses.
HiMu 80	(12)	C 0.05; Ni 79.0; Mo 4.0; Fe bal.	Magnetic applications.
Supermendur	(6), (8), (15)	Co 49; Vi 2; Fe bal.	Magnetic alloy.
Core Iron	(12)	C 0.06; V 0.10; Fe bal.	High resistance to magnetic aging.
Polar	(11)	Modified 1030	Pole pieces for magnetrons.
Halmo	(1)*, (2), (4)*, (5), (6), (7), (10)†, (14)*	C 0.60; Cr 4.7; Mo 5.2; V 0.5; Si 1.1; Fe bal.	High-temperature service to 500° F.
HTB-1	(1)*, (6), (7), (10)†	C 1.00; Cr 1.45; Al 1.0; Fe bal.	High-temperature bearings.
MCS	(4)*, (7)	C 0.70; Cr 3.5; Mo 5.5; Si 1.0; Fe bal.	High-temperature bearings.
VSM	(12)	C 0.70; Cr 3.0; Mo 5.2; Si 1.1; Fe bal.	High-temperature bearings, valve seat inserts.
Unimach No. 2	(4)*	C 0.50, Cr 5.0; Ni 1.5; Mo 1.4; V 1.0; Si 1.0; Fe bal.	Structural steel for high-temperature service.
Extrad	(9)†	C 0.35; Cr 5.0; Mo 1.4; W 1.25; V 0.20; Si 1.0; Fe bal.	H-12 toolsteel with silicon; heat resistant parts.
Kovar	(12), (15)	Ni 29.0; Co 17.0; Fe bal.	Glass sealing alloy.
TBS-600	(10)†	C 1.0; Cr 1.4; Mo 0.30; Si 1.00; Fe bal.	High-temperature bearings.
CBS-600	(10)†	C 0.20; Cr 1.5; Mo 1.0; Si 1.1; Fe bal.	High-temperature bearings.
HS-220	(10)†	C 0.30; Cr 1.2; Ni 2.0; Mo 0.45; Si 0.55; Fe bal.	Ultra-strength steel.
HS-260	(10)†	C 0.40; Cr 1.4; Ni 2.2; Mo 0.50; Si 0.60; Fe bal.	Ultra-strength steel.
Peerless 56	(6)	C 0.40; Cr 3.25; Mo 2.5; V 0.33; Si 1.00; Fe bal.	Super-strength structural parts
Molybdenum	(4)†, (11)†	(1) Pure, (2) Ti 0.5	Jet engine parts.

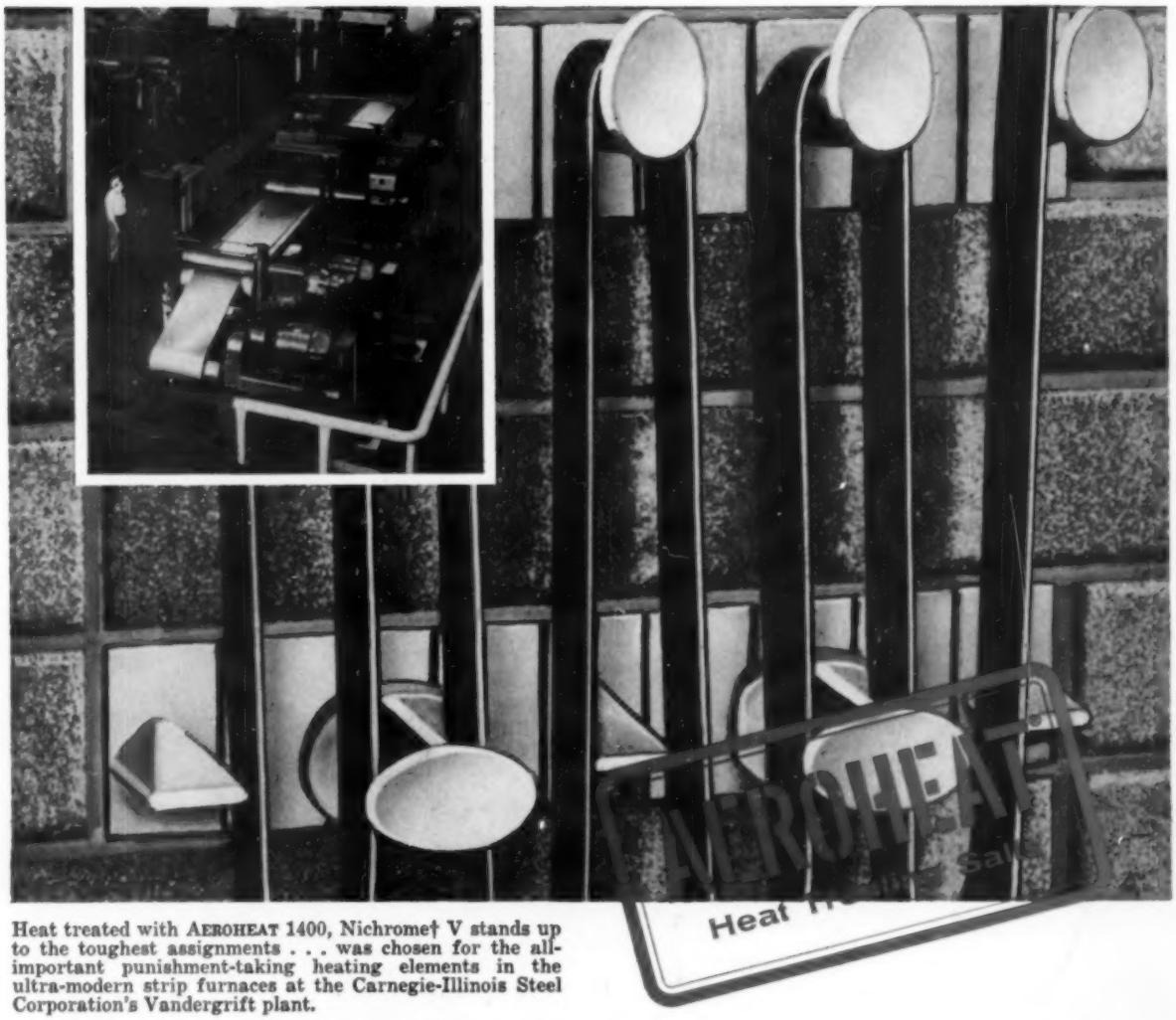
Vacuum Melted Alloys

Key to Source:

(1) Allegheny Ludlum Steel Corp., Pittsburgh.
(2) Metallurgical Products Dept., General Electric Co., Detroit.
(3) Haynes Stellite Co., New York.
(4) Universal-Cyclops Steel Corp., Bridgeville, Pa.
(5) Utica Metals Div., Kelsey-Hayes Co., Utica, N.Y.
(6) Vacuum Metals Div., Crucible Steel Co. of America, Syracuse, N.Y.
(7) Vanadium-Alloys Steel Co., Latrobe, Pa.
(8) Cannon-Muskegon Inc., Muskegon, Mich.
(9) Midvale-Heppenstall Co., Philadelphia.
(10) Timken Roller Bearing Co., Canton, Ohio.
(11) Allvac Metals Co., Monroe, N.C.
(12) Carpenter Steel Co., Reading, Pa.
(13) Firth-Sterling, Inc., Pittsburgh.
(14) Latrobe Steel Co., Latrobe, Pa.
(15) Westinghouse Electric Corp., Blairsville, Pa.
(16) Mallory-Sharon Metals Corp., Niles, Ohio.
(17) International Nickel Co., Inc., New York.

*All alloys are induction vacuum melted unless source is marked with asterisk, which indicates a consumable electrode melted grade is also available.
†Indicates only consumable electrode melted grade is available.
‡Combination induction vacuum, consumable arc remelting.
§Vacuum skull casting.

NOTE: This data sheet represents the combined contributions of 17 manufacturers of vacuum-melted alloys. We thank them all for their gracious assistance; without their help this list could not have been compiled. In the information listed inside the fold some compromises had to be made with regard to trade names because of space problems. However, although some trade names have been eliminated, all vacuum-melted alloys reported by each contributing manufacturer are listed. To the best of our knowledge, all manufacturers in the country are included. C.R.W.



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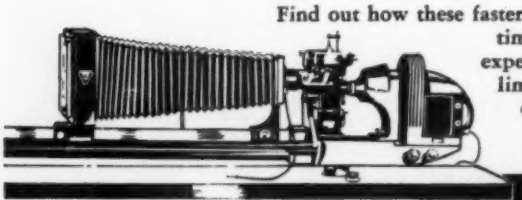

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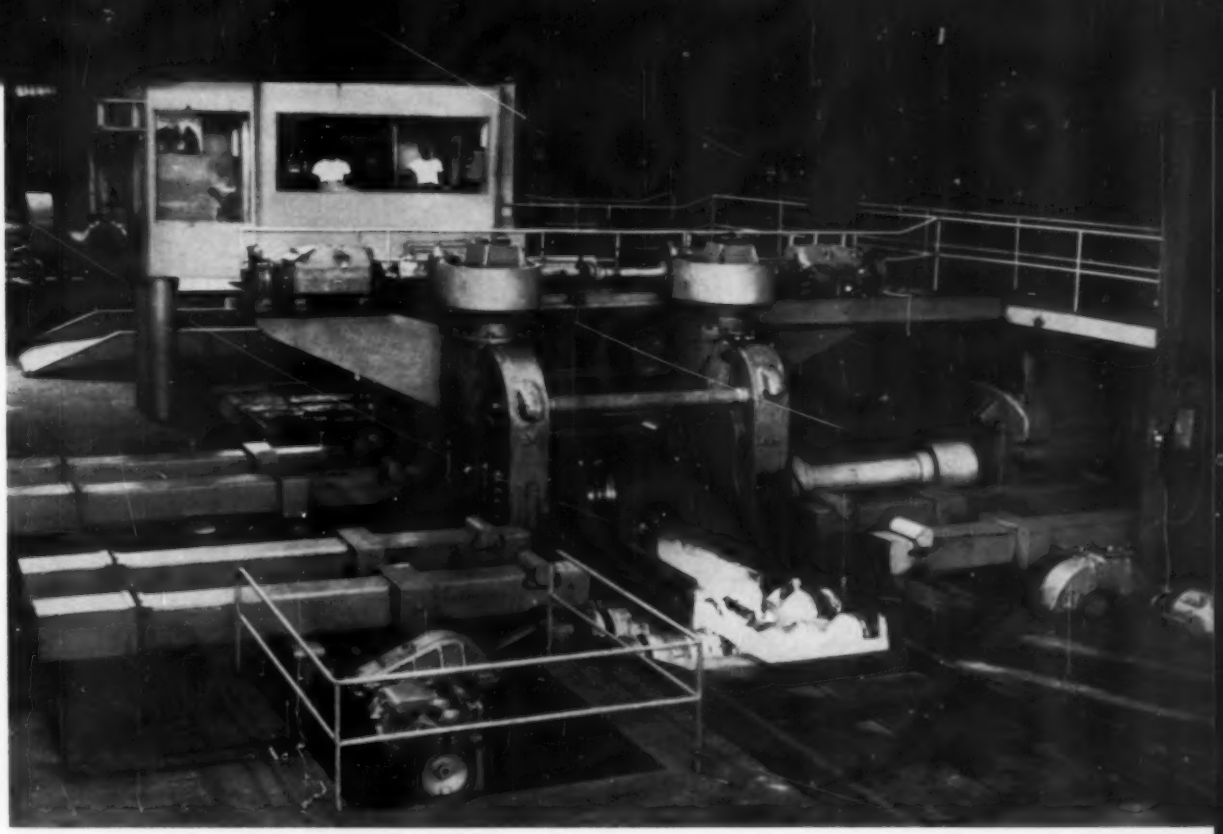

Fig. 4 – This 32-In. Cogging Mill Was Installed Last Year to Handle Superalloys and High Speed Steels. It's the first time a rolling process has replaced hammer forging for large-scale conversion of these ingots into billet or slab sizes. (Courtesy Latrobe Steel Co.)

of magnesia or zirconia. If magnesium is the reaction product, it will boil off, but zirconium and other trace elements are absorbed by the melt. This characteristic led to the discovery that both zirconium and boron improved physical properties of high-temperature alloys; in many of them they are now a standard addition.

While vacuum induction melting generally produces the purest product, some drawbacks exist. Mechanical difficulties which attend the maintenance of a high vacuum in a furnace chamber limit the heat size. At present, builders feel that a 5000-lb. unit, such as is now being completed by Utica Metals Div. of Kelsey-Hayes Co., is the practical limit. Center segregation in the solidifying ingot is another problem. It can be minimized only by proper mold design and cooling practice. For example, the metal in the hot top is usually kept molten to feed the ingot as it freezes. The Carpenter Steel Co. uses a novel ingot mold with a heavy copper stool (for rapid heat removal). The mold is designed to produce a short, squat ingot; almost all freezing is from bottom to top forcing inclusions to the top and minimizing segregation to a great extent. One peculiar problem some vacuum melters face is "icing" in the furnace. When small water leaks occur, the water sprays into the vacuum; its expansion is so rapid that it cools below 320° F., and mush ice actually forms around the leak. It seems unlikely that any other melting process could ever be subject to such an oddity.

Consumable Electrode Melting

Some segregation problems can be solved by remelting. When arc remelting is done in a vacuum, as in the consumable electrode process, the original advantages realized by vacuum melting are retained. This process requires an electrode of the desired alloy. It hangs in the evacuated chamber, and a low-voltage, high-amperage arc strikes between the end of the electrode and the "starting pad"*. As the arc slowly melts the electrode, the molten metal resolidifies below in a water cooled copper mold. The furnace can be likened to a gigantic automatic welding machine.

The process has several advantages: Outstanding is the fact that much larger ingots can be made than are possible with the induction furnaces. At the end of 1957, a 12,000-lb. ingot had been produced, and an 18,000-lb. ingot is predicted for this year. Another advantage is that segregation problems are greatly lessened. Proper adjustment of amperage and voltage

*A starting pad is a slab of metal, usually vacuum melted and of the same grade as the electrode, placed in the bottom to protect the copper mold.

makes it possible to maintain a shallow pool over the cross section which solidifies rapidly in the water cooled mold.

A limitation of consumable electrode meeting is that the quality of the remelted ingot is limited by the quality of the electrode; an air-melted electrode, for example, contains inclusions some of which will reappear in the recast ingot*, though their distribution is considerably better. Gases boil off readily. If vacuum-melted material is used for the electrode, costs shoot up markedly; however, aircraft requirements today are such that this double-melting process is rapidly gaining prominence. The cleanliness of the vacuum-melted electrode plus the virtual absence of segregation in the recast ingot results in an excellent product.

Degassing

Strictly speaking, this is not a vacuum melting process. Steel is melted by conventional practices in an electric furnace or an openhearth, and tapped into a ladle in the usual manner. The ladle is then placed atop a "pony" ladle over the vacuum chamber containing the ingot mold, as Fig. 3 shows. The small ladle is filled; when its stopper is opened, molten metal burns through the aluminum seal and pours into the mold. Though the pressure is fairly high (between 200 and 1000 microns), hydrogen, because of its high diffusivity, boils off rapidly; values below 1 ppm. in the ingot are consistently reported. The ability to remove hydrogen plus its practicality for producing very large ingots (up to 500,000 lb.) makes this method extremely attractive for steels used in steam turbine and generator rotor forgings. Flaking difficulties are virtually eliminated at a comparatively low cost – authorities report this to be less than one cent per lb.

Each vacuum processing method has its advantages and disadvantages (Table II). The process to use depends not only on the properties needed but also on the economic factors involved. Table II gives the characteristics of each melting process along with the products being made.

Quality Control

In making such high-standard materials as these, quality control is all-important; every phase of melting and fabrication must be carefully regulated. For example, in the induction process, charge materials must be of high purity. Chemical analysis is essential for each incoming lot of scrap and alloy addition, as is careful weighing of every element in the charge.

While the charge is melting in the crucible, the maintenance of a constant high vacuum is usually mandatory. Leak rate is checked at short intervals by closing off valves to the pumps. When leaks occur, the chamber is flooded with helium and the leak location determined by a mass spectrometer. Determination of the leak rate is also necessary to ascertain the point at which the oxygen and carbon are low enough to permit addition of reactive elements. Occasionally, pressures of a few millimeters are needed for control of the furnace. They can be achieved by allowing the evolved gases to build up or by introducing an inert gas such as argon.

The control measures in the consumable electrode process are aimed at maintaining a low vacuum – under 0.5 mm. is preferred. Above this, the arc will not strike the bath consistently; instead it will wander up the electrode and strike across the copper crucible, often burning holes in it. This is a dangerous condition and in the past it has resulted in bad accidents. The arc power should also be kept at a high value for stability. Since the quality of the remelted ingot depends so much on the quality of the electrode, methods to control this are obviously needed. The electrode surface is machined to remove the rough surface; tests to insure a sound ingot of the proper analysis are also necessary.

Forging and Rolling

Shaping practices for vacuum-melted ingots are similar to those used for air-melted superalloys and toolsteels. Most ingots are forged*, light pressing being used at first to break up the large as-cast grains. When forging is completed, the surface is conditioned by swing grinding. This is the preferred method for conditioning; it also follows each rolling operation to prevent the surface from breaking up during subsequent working. Because of the narrow working range of these highly alloyed materials, temperatures must be carefully checked in all operations. Most of the alloys produced by vacuum melting can be furnished in the standard sizes of bars, rods, and sheets; a number of special shapes are available too.

*It is true that the arc is hot enough to decompose nitrides, oxides, and sulphides, providing equilibrium can be reached. However, the rapid uncontrolled melting rate inherent in this process makes this next to impossible.

*The Latrobe Steel Co. and the Haynes Stellite Co. have special mills capable of rolling superalloy ingots. (Fig. 4 shows Latrobe's.)

Table II – Comparison of Melting Processes

Type of Process	Weight*	Advantages	Disadvantages
Vacuum degassing	500,000 lb.	Low operating and equipment costs; few size limitations.	No alloying possible; less removal of O_2 and N_2; regular ingot problems; quality depends largely on original air melt.
Vacuum induction	3,000	No slag-air contamination; best total degassing possible; Mn and Si not required; permits more use of reactive elements such as Ti, Al, B and Zr; good refining ability; self-sufficient process; good control.	High operating cost; small batches; refractory contamination; regular ingot problems; raw material limitations; highest equipment cost.
Air melt consumable-electrode arc remelt	13,000 (26 in. diameter)	Improved ingot structure; no slag-air-refractory contamination; good control; fair degassing ability.	Intermediate operating cost; limited refining ability; not self-sufficient — partially dependent on electrode quality; high equipment costs.
Induction-vacuum consumable-electrode arc remelt	3,000 (16 in. diameter)	Combines advantages of two processes above.	High cost.

*Largest ingot or casting currently being made.

Inspection

Most customers for vacuum-melted alloys feel that the material should be as close to perfect as possible – an understandable view considering their high cost. This means that inspection of material before shipment must be thorough. It generally includes 100% inspection of the surface by some detection method (such as Zyglo), stress-rupture tests, cleanliness tests by microscope. Often, special tests are required by the customer when the material is to be used in an unusual application. It often happens that 5 to 10% of the heat is used up by testing; this adds to the cost, a fact sometimes unappreciated by buyers. Such extensive testing is generally needed, but it is a definite factor in the high cost of vacuum-melted alloys.

Applications

At present, most of the alloys produced by vacuum melting go into jet engines. They are used for parts such as turbine buckets, casings, nozzle diaphragms, afterburner parts, bolts – in short, wherever high-temperature, high-strength properties are essential. However, other applications exist, and more are being added all the time. One potent area is high-temperature bearings. A large amount of 52100 steel is being melted for this purpose now. Numerous other high-temperature fields are also open to vacuum-melted metals – exhaust valves, superheater tubes, steam turbines, high-pressure vessels, and the like. It seems probable that any part subject to heat and stress would benefit from being made of vacuum-melted materials.

Toolsteels are another field where vacuum melting is becoming important. With the coming of automation and the constant need for increased feed and speed rates, toolsteels need to be stronger and tougher than ever. The general improvement in properties imparted by vacuum melting makes this possible.

Vacuum is also offering competition to the standard air-melted grades. For instance, A.I.S.I. 4340 is melted in large tonnages by most steelmakers; yet, orders for this grade are constantly being received by vacuum melters. Why? The answer is simple – vacuum melting (usually consumable electrode melting) gives properties that air melting cannot – at least, consistently. With the advent of ultra high-strength steels, transverse ductility, particularly in the center, has become a specification. A number of aircraft builders now use A.I.S.I. 4340 for the 260,000 to 280,000-psi. strength level, and they are finding the improved properties of the vacuum-melted material appealing despite the added cost.

The future should see considerable use of vacuum melted alloys as ultra-thin strip for the fabrication of honeycomb and other sandwich structures for strength at temperature levels reached in high-speed flight. Engineers working on future aircraft and missile designs are already experimenting along this line.

Production of Discaloy by Vacuum Arc Melting

*By D. R. CARNAHAN**

Discaloy is now being produced by the consumable-arc process. Problems solved during development of the commercial melting method are discussed. (C5h, 1-73; SGA-h)

CONSUMABLE-ARC REMELTING, although considered expensive, was developed out of absolute necessity for melting titanium and zirconium. These metals are highly reactive and are easily contaminated by both atmosphere and refractory. Recently, industry has adapted this process to refine nonreactive metals and their alloys. Properties of superalloys are substantially improved by this process; however, very little detailed information has been published on its production capabilities. Therefore, we made a pilot-plant production run of 1200-lb. ingots of Discaloy† 12 in. in diameter.

The equipment used in this pilot run was a vacuum-arc furnace with pumping accessories which made it possible to operate at pressures of 2 to 10 microns with a leak rate of from 1 to 3 microns. The power supply is capable of 15,000 amp. at 35 v. A 12-in. mold with a removable bottom (attached to a hydraulic ram) was used; the ingot could be lowered to floor level. The arc length was controlled by a voltage regulator.

Electrode Preparation

The processing of electrodes presented quite a problem. They were first used as cast; however, this resulted in longer pumpdown times during furnace evacuation and excessive outgassing during melting. Also, if any part of the air-melted electrode contained excessive dirt, this appeared in the remelted ingot. For this reason, hot tops were cut from electrodes and any electrode with an excessively deep pipe cavity was not used.

We have found that air-melted electrodes must be thoroughly conditioned. Those used in this pilot-plant run were assemblies of 7-in. round machined billets known to be internally sound.

At first, we only required starting pads of the same composition as the material being melted. In one instance, however, part of the pad exploded shortly after the arc was struck. We then altered the melting procedure to insure that only closely inspected pads free of trapped gas or water were used. While cracking of the pad and large pressure rises at the arc strike period were eliminated, microscopic examinations showed excessive dirt in the bottom portion of the ingot.

The melting procedure was again changed to include the use of pads that were cut from vacuum-arc melted ingots. This has reduced considerably the pressure rise that occurs during the arc strike period and has totally eliminated excessive dirt in the bottom sections. This last procedure was used in this pilot run.

Some time has been spent on striking the arc

*Engineer, Westinghouse Electric Corp., Blairsville, Pa.

†Registered trade name, Westinghouse Electric Corp. For composition, see data sheet, p. 96-B.

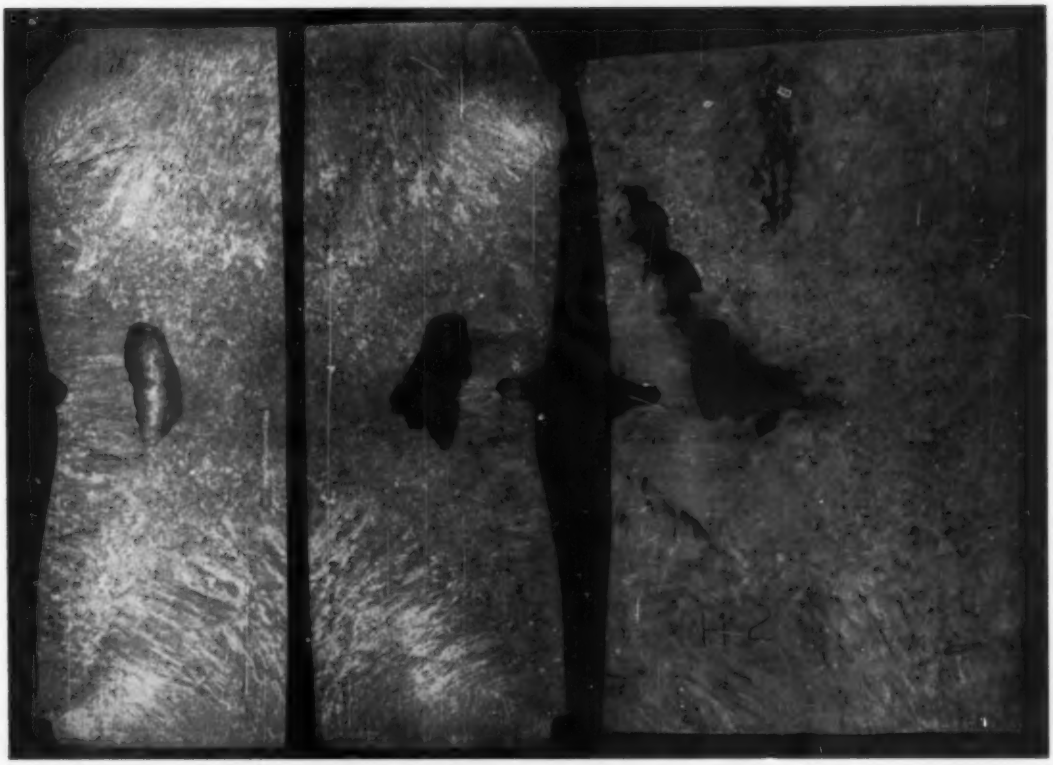

Fig. 1 — Improvement in Hot Tops. Right view shows one of the early hot tops; two views at left show one produced by the final practice

directly on the water cooled copper bottom. We can do this to the extent that the arc does not go through the water cooled bottom, but the degree of attack is such that the bottom life would be very short. More work must be done before this method of arc strike becomes a standard procedure.

Melting Rates

These were influenced by two things: First, we wanted progressive solidification; second, an acceptable surface.

In earlier heats, amperages of 10,000 to 12,000 were used with voltages ranging from 26 to 30. Subsequent inspection showed that pool depths were much too deep, and the as-cast structures were comparable to those of air-melted ingots. There was no progressive solidification. In one instance the columnar grains were 5 in. long; there was only a 2-in. cylinder of equiaxed grains in the center. More recently, ingots were melted using 7000 amp. and voltages of from 22 to 24. We found that columnar grains were reduced considerably and progressive solidification had occurred. Figure 1 shows the results of the changes in melting practice, and Fig. 2 shows a typical cross section. Equiaxed small grains have been produced by progressive solidification and rapid cooling. In the pilot run 7000 amp. and 22 to 24 v. were used.

Hot Top Procedure

Large pipe cavities, formerly a problem, were reduced in two ways. We reduced the power input during the hot top period (making the pool depth much shallower), and increased the time of hot topping. The yield jumped from 62 to 77%. The 28% loss in earlier heats also included bottom loss and the material loss during machining of the finished ingot. The hot top loss of 20% was reduced to 10%.

Good hot topping procedure is also important for cleanliness throughout the ingot. When the cycle is too short and power inputs too low, dirt that has floated out of the previously melted metal will be trapped deep within the ingot. In this run we used a 20-min. cycle — 5 min. at 5000 amp., 5 min. at 3000 amp., 5 min. at 2500 amp., and 5 min. at 2000 amp.

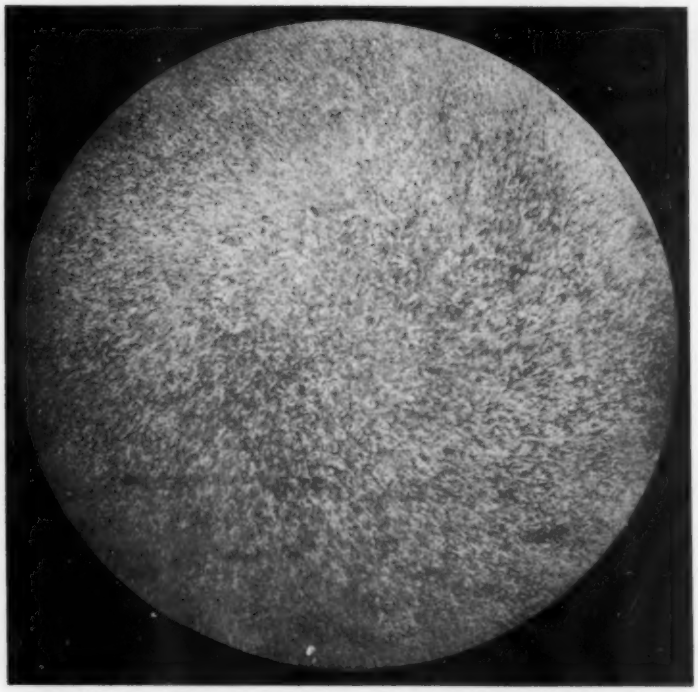

Fig. 2 – View of Discaloy Ingot Cross Section. The melting procedure gives an ingot with a large, equiaxed central zone; this is desirable

Stirring

We made eight of our heats with the aid of a magnetic stirring coil and discovered that higher magnitudes of stirring resulted in very poor surfaces. Though a finer grain size appeared in stirred ingots, a segregate also occurred. On the basis of this, we decided to melt all future ingots, in this particular melting schedule, without stirring.

Production Run

The electrodes used were 17 ft. long; to fabricate them, we welded two 7-in. diameter machined Discaloy billets. All billets were thoroughly tested for internal soundness. With a starting pad of the same grade (which had been consumable-arc melted), melting began. After an initial rise in pressure, the vacuum was maintained at 4 microns under a steady current of 7000 amp. At 22 to 24 v., melting took about 3 hr. for each ingot, including the 20-min. hot topping schedule.

A total of 21 ingots was produced in 168 hr. which figures to an average of 8.0 hr. for each ingot. This average includes, besides melting furnace preparation (1.2 hr.), pump down (0.63 hr.), cooling time (0.63 hr.), unloading and cleaning time (0.95 hr.), delays (0.90 hr.), and power failure (0.79 hr.). The final product was an ingot 12 in. in diameter and 48 to 50 in. long which weighed about 1500 lb.

Tests made on these ingots proved that segregation was much less and mechanical properties were significantly better than in conventional air-melted electrodes.

Segregation of titanium in the vacuum-arc melted Discaloy was generally low as compared to the air-melted product. The average variation in an air-melted ingot, measured from top to bottom, was found to be around 0.30% compared to 0.17% for the vacuum-arc melted ingots.

The specification limits for Discaloy pancakes are 10 hr. minimum rupture life at 60,000 psi. with 5% minimum elongation. Testing was performed at 1200° F. Typical properties follow:

	Rupture Life	Elongation
Air melted	10 to 75 hr.	3 to 14%
Vacuum-arc remelted	18 to 94	14 to 38

Conclusions

1. The cleanliness of the electrode and starting material have a large effect on the cleanliness of the vacuum-arc melted ingot produced.

2. A procedure has been established for the production of 12-in. diameter Discaloy ingots having a progressively solidified structure, sound surface and high ingot-to-product yield.

A User Looks at . . .

Cleanliness of Vacuum-Melted Alloys

*By DONALD E. NULK**

The problem of "how clean is clean" is becoming more acute with the development of new superalloys containing increased amounts of reactive elements. Carbides and nonmetallic inclusions interfere with fabrication, influence service conditions and decrease the effectiveness of the alloy from the standpoint of chemical balance. Three methods may be used to measure cleanliness: modified A.S.T.M. inclusion rating, frequency/severity rating and metallographic classification. (N12, N3, M27, C25; SGA-h, 9-69)

THE GAS TURBINE INDUSTRY and allied fields which use vacuum-melted superalloys have many problems associated with cleanliness. It seems almost anomalous to say there are cleanliness problems with vacuum-melted alloys. This article is written from the standpoint of a user surveying problems associated with precision forging these alloys. We are particularly concerned with gas turbine vane and bucket forgings, although some applications are broader.

When the vacuum-melting process was first introduced, it gave a tremendous improvement in the cleanliness of bearing alloys and many specialty steels. Then, it was discovered that this process made it possible to produce alloys which had not been practical to produce by air melting. These are nickel-base materials containing active elements such as titanium, aluminum, zirconium, and boron. They have proven themselves as good high-temperature alloys. Precipitation hardening is the primary means of increasing their strength. An attempt to air melt these alloys, originally resulted in partial or total loss of the critical alloying elements, or in their combination with interstitial elements, such as nitrogen and oxygen, which made them ineffective for their primary job. The physical properties of the alloys could not be reproduced because of the difficulties in controlling the active elements.

A whole family of these superalloys have come into use and more are being developed. A partial list is shown in Table I. Although they differ in percentages of critical elements, the basic metallurgical principles are similar. Poor cleanliness can affect them in one or more of the following ways: (*a*) It can interfere with fabrication; (*b*) it can influence service conditions, especially fatigue; (*c*) it can decrease the effectiveness of the alloy from the standpoint of chemical balance. To understand the effect of poor cleanliness condition, we will discuss some metallurgical aspects of the alloys and their relationship to the conditions described above.

Carbides

It is not possible to get a single-phase structure in the solution-annealed condition with these alloys. It is doubtful whether the carbides are in complete solution at the pouring temperature. There is evidence they are never in complete solution at the maximum solution-annealing temperature which is governed by the limits of intergranular melting. Therefore, our

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first problem is associated with the size, shape, and distribution of carbides.

Obviously, a homogeneous distribution of carbides is desirable; a fine dispersion is generally recognized as preferable. However, these alloys are prone to gross segregation during melting; it's desirable to have a small ingot to minimize segregation. Another way of minimizing segregation is by hot working the ingot. Here, the greater the percentage of reduction from the ingot size to the final bar stock, the greater the amount of homogenization. A compromise between these two opposing factors is evident. Until recently, the facilities of most mills restricted them from making large ingots of certain alloys, such as Udimet 500. With this limitation, it was possible to produce a homogeneous forging stock in small bars but larger forging stock was rather nonhomogeneous.

The size and distribution of carbides in many of these alloys cannot be appreciably altered by solution annealing. On the other hand, prolonged holding at elevated temperatures will dissolve a sufficient amount to affect the morphology and distribution of total carbides after re-precipitation. Such a prolonged total heating time could result from a forging configuration that would require many forging sequences. The re-precipitation of dissolved carbides would be subject to the normal energy considerations of such a process. There is great tendency for grain-boundary precipitation, and therefore the grain size becomes an interrelated problem. In such alloys as Udimet 500, grain-boundary precipitation of $M_{23}C_6$ carbides can adversely affect the ductility of the end product.

Nonmetallics

These are primarily oxides and nitrides. Alloying elements such as titanium and boron, in combination with these intermetallic elements, are ineffective for their primary function. Presence of oxygen and nitrogen is unintentional. Some of the ways they are introduced into the melt are: (*a*) dissolved gases and inclusions in metal additions; (*b*) occluded gases attached to metal additions; (*c*) the atmosphere in the melting chamber is not a perfect vacuum; and (*d*) reactions with mold and crucible.

Control of Grain Size

This is an important factor. Microscopic examination of stress-rupture samples near the area of fractures reveals a series of microfractures in the specimens parallel to the ones that propagated to complete failure. In a duplex grain size, or a banded structure, one can observe many fractures in the coarse-grained areas and practically none in the fine-grained areas adjacent to the main fractures. In some instances, a large crack propagates to the fine-grained area and appears to be stopped by the fine-grained structure as illustrated by the photomicrograph in Fig. 1.

There are two possible explanations for this behavior: First, the fine-grained structure can readjust itself to redistribute the load by localized yielding. The coarse-grained area, being

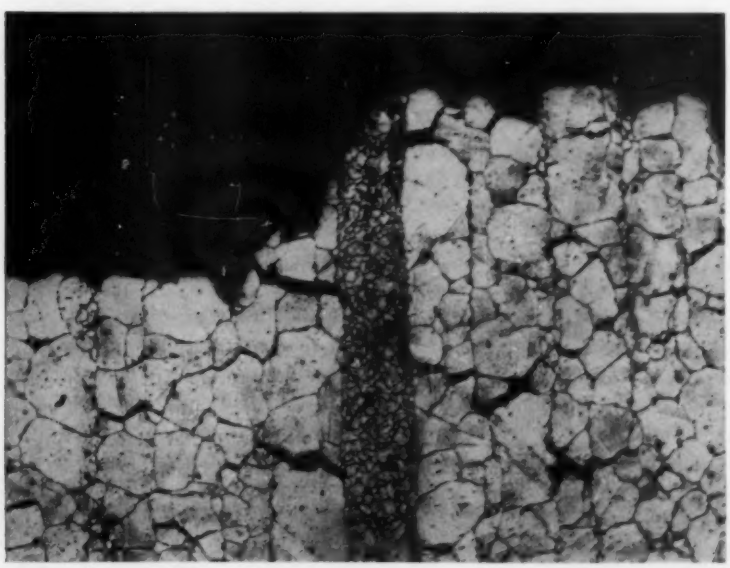


Fig. 1 — In This Stress-Rupture Test on Udimet 500, Large Cracks Have Propagated to the Fine-Grained Area and Appear to Have Stopped There. Specimen also illustrates fractures parallel to a stress-rupture failure. 100×

Table I – Typical Vacuum-Melted Superalloys

	Waspaloy	M-252	U-500	M-308	Rene 41	U-700
Iron	1	2	1	41	2	—
Nickel	56	55	53	32	53	51.0
Chromium	19	19	17.5	14	19	17.0
Cobalt	13.5	10	16.5	—	11	18.0
Molybdenum	4.25	10	4	4	10	4.0
Tungsten	—	—	—	6.5	3.2	—
Titanium	3	2.5	3	2.2	1.7	4.0
Aluminum	1.25	1.0	3	0.2	0.1	4.0
Carbon	0.05	0.15	0.05	0.05	0.3	0.15
Manganese	0.25	0.3	0.5	0.02	0.3	—
Silicon	0.5	0.3	0.5	0.02	—	—
Zirconium	0.1	—	—	0.2	—	—
Boron	0.006	0.003	0.005	—	0.002	1.0
Columbium	—	—	—	—	—	—

less mobile, carries a disproportionate percentage of the total load and thus fails prematurely. The second point is that fine-grained regions of specimens with banded structures usually have a larger percentage of carbides and nonmetallics. It is possible that they also have a larger percentage of alloying elements which contributes to the strengthening of the structure. If this is true, the failure in the coarse-grained area would be due to the lower load-carrying capacity of the large grains.

It is probable that both factors contribute to early failure in the coarse-grained areas. We find that a homogeneous, coarse-grained area and a homogeneous, fine-grained area will both have a larger load-carrying capacity than the duplex grain structure. The duplex structure described here refers to alternate bands of large and fine-grained area. It should not be confused with the selective forging process which gives a coarse-grained area in the center of the forging and a fine-grained one on the leading and trailing edge of gas turbine buckets. In the latter instance, a major load-carrying capacity is designed into the center of the bucket.

Control of grain size begins at the mill. The ingot should have sufficient reduction to insure even, recrystallized grains. The ingots should be sufficiently homogeneous, avoiding banded carbide structures, to cause a minimum of interference with this process. In alloys where hot and cold working occurs, the percentage reductions and forging temperature should be carefully controlled.

The Role of Boron

The fabrication metallurgist must work with many alloys containing boron. Although theoretical considerations are not completely resolved, we believe boron has the following functions:

1. It fills lattice dislocations and grain-boundary areas of low density, preferentially. This minimizes the amount of grain-boundary precipitation and encourages general precipitation of carbides dissolved in the forging process. The net result is a more ductile alloy for a given amount of carbide precipitated and for a given grain size.

2. The action of boron in filling lattice faults in the grain boundary and dislocation sites can increase strength by two mechanisms: decreasing lattice location sites and increasing interatomic attraction because of a more closely packed lattice.

3. Another result of boron's preferential solution can be associated with the precipitation phenomenon. There would be a tendency to form general precipitation earlier in the precipitation (or aging) heat treatment. It is possible that the absence of boron would lead to an overaged condition in the grain boundaries, whereas its presence would give more uniform precipitation. This could possibly increase the effectiveness of a given percentage of precipitation hardening constituent.

4. An excess of boron, over that required to fill the lattice faults, could contribute toward solid solution hardening, comparable to any interstitial hardening phenomenon. In the low boron ranges, there is little apparent effect of a change in boron over a rather wide range. It would appear that there is little contribution to solid solution hardening in this range (0.003 to 0.012%). On the other hand, boron is probably quite active in the higher boron ranges used in such alloys as Udimet 700.

5. Boron can act as a scavenger tying up dissolved interstitial elements. Such nonmetallics could contribute toward grain refinement and, possibly, increase the effectiveness of other alloying elements, which would otherwise combine with the interstitials. We believe this is a secondary effect, which is unimportant if mill processes are good.

Analysis of a series of superalloy heats leads to a confusing pattern of varying mechanical

properties. For example, there seem to be wide variations in stress-rupture properties which cannot be easily traced to chemical composition. It seems reasonable to assume that when titanium is tied up as titanium carbo-nitride, or boron as boron nitride, or aluminum as aluminum oxide, the elements are ineffective in performing their major roles. We feel there is a direct comparison between the observable cleanliness rating of heats of these alloys and the amount of available alloying element.

One simple test to prove this was made on two heats of Waspaloy, neither of which was particularly clean. One heat was considerably dirtier than the other. Samples of these heats were dissolved in methylene bromide and the residue was weighed and analyzed by spectrographic means. All chromium, titanium, magnesium, and calcium were assumed to be in the combined form designated below. On this basis, the analysis of inclusions indicates that the major contributing factor toward increasing the inclusion rate in these alloys is the presence of interstitial elements such as nitrogen and oxygen.

Chemical Composition	Relatively Clean Heat	Relatively Dirty Heat
Cr_2C	25 units	35 units
TiCN	25	50
MgO	< 1	15
CaO	< 1	15

The residue of the dirty heat had twice the weight of the residue of the clean heat. The chemical compositions are oversimplifications. The spectrographic analysis is an approximation. Nevertheless, this indicates a general trend.

Homogeneity and Fabrication

Now, let's consider the interrelationship of all these factors. Ideally, we like to start with homogeneous materials and forge to a configuration that makes it possible to get relatively uniform reduction, a refined grain size, smooth flow lines, and consistent properties. If we start with forging stock that is nonhomogeneous with regard to grain size and carbide distribution, we can expect difficulty in obtaining homogeneity in the end forging. Some configurations of parts make it difficult to devise forging techniques which will yield a uniformly worked structure. Such forgings make it difficult to improve the homogeneity of the initial forging stock. It is possible to accentuate grain size inhomogeneity when making certain forging configurations.

If the end product has scattered or banded carbides and varied grain size, we can expect a sacrifice in mechanical properties. The load cannot be uniformly distributed. These superalloys do not permit a wide range in percentage deformation in a single forging blow. Therefor, it is not easy to work the alloy, without regard to percentage deformation, up to the coining operation and correct the grain size in the final blows. Homogeneity cannot be readily improved by increasing the number of forging cycles since this increases the amount of dissolved carbides. These carbides later re-precipitate in the grain boundaries and can accentuate embrittlement.

The higher the percentage of oxygen and nitrogen in superalloys, the less effective the critical alloying elements will be. We have shown that a lower cleanliness rating is indicative of a higher oxygen and nitrogen content. Elements such as boron tend to offset certain deleterious effects by encouraging the re-precipitation of carbides throughout the grains instead of grain boundaries.

Stringers

Aside from the physical and chemical aspects of cleanliness, we have manufacturing (or forging) problems associated with stringers. Stringers tend to encourage seams, laps, and cracks when force is exerted on the alloy perpendicular to the axis of the stringer. If we ignore scrap and repair cost associated with these problems, we still have the inspection problem after the part is finished. Any seams or heavy inclusion areas tend to show a Zyglo indication which is difficult to evaluate. Bucket designers feel these should be eliminated since they constitute stress-raisers. Costly repair techniques result from the use of dirty alloy, and it is questionable whether all of these inherent failure centers are ever removed.

Service Life

In turbine bucket manufacture, we are less concerned with stringers than in some other applications, because the major loading axis is parallel to the axis of the stringer. Stringers here tend to decrease the triaxial stress component, which could increase the strength-carrying capacity in the direction parallel to the stringer. On the other hand, some of the fatigue or bending stresses tend to be in a direction normal to the loading axis. These stresses could be amplified by stress-raisers from stringers or heavy inclusion areas.

Heavy stringers in the center of the bucket have a negligible effect on fatigue and bending stresses. Those near the surface, which could contribute, would tend to open up during forg-

ing, forcing a repair or rejection of the part. Therefore, chances are slight that a customer would receive a bucket with low fatigue properties because of stringers. Nevertheless, it constitutes a serious enough problem to make it inadvisable to continue this compromised quality if it is possible to improve the condition.

Routes to Better Alloys

Improvements are being made in vacuum systems and melting practice. However, so long as the yield of vacuum induction product is as low as it is, a major problem will exist. Obviously, it is not possible to avoid using melt scrap when producing an expensive material that is giving only a 50% yield. Yet, when scrap is re-used there is a chance of increasing the interstitial level, just as tramp elements have increased in mild steel made in the open-hearth.

It seems that the induction vacuum-melted product will never reach the cleanliness we feel is desirable on some of the more critical superalloys. It may be possible to combine the induction process with the vacuum arc process to get a cleaner, more consistent product. The first production heats made by this process show promise in improving cleanliness but it is too early to establish a pattern. Theoretically, this gives chemical control in the induction vacuum process which is needed to make the original electrode. Arc melting it under vacuum results in additional out-gasing, some homogenization and also increases the maximum size of the ingot that can be produced. Waspaloy ingots 15 in. in diameter have been made in this way.

One recent innovation has been the use of an ingot which controls the cooling rate so that a greater percentage of inclusions tend to float to the top. Another modification is the use of a low-frequency induction coil which stirs the melt. This decreases the total time of the melt and tends to expose a greater percentage of it in the shorter space of time to the vacuum surface. Presumably this results in better out-gasing and more thorough mixing of critical elements.

Improvements have been made in air-melting techniques. An air-melted heat of an alloy in this series can be remelted by the vacuum arc technique to produce a rather homogeneous product. Some very clean heats have been made by this method. There is some doubt as to the ability to control chemistry under such a method, although some claims made are remarkable.

Until industry can make clean material with good mechanical properties on a reproducible basis, regardless of bar stock size, there will be a problem in cleanliness evaluation. At the present time we use three evaluation methods.

Modified A. S. T. M. Inclusion Rating

This test is used when quality of product is extremely poor. It provides a measure of continuous stringers as well as information on background condition. We hope the continuous stringers can be eliminated with advances in techniques of melting. The mills have not yet shown their ability to eliminate them entirely in large bar sizes. However, users of small bars would rarely run into material as poor as the typical rating given in the example below.

The system is a modification of the A. S. T. M. Rating Standards (Vol. 1, 1955, p. 1650). A typical rating would be:

$$75\,A^{14} - B\,5\,T+$$

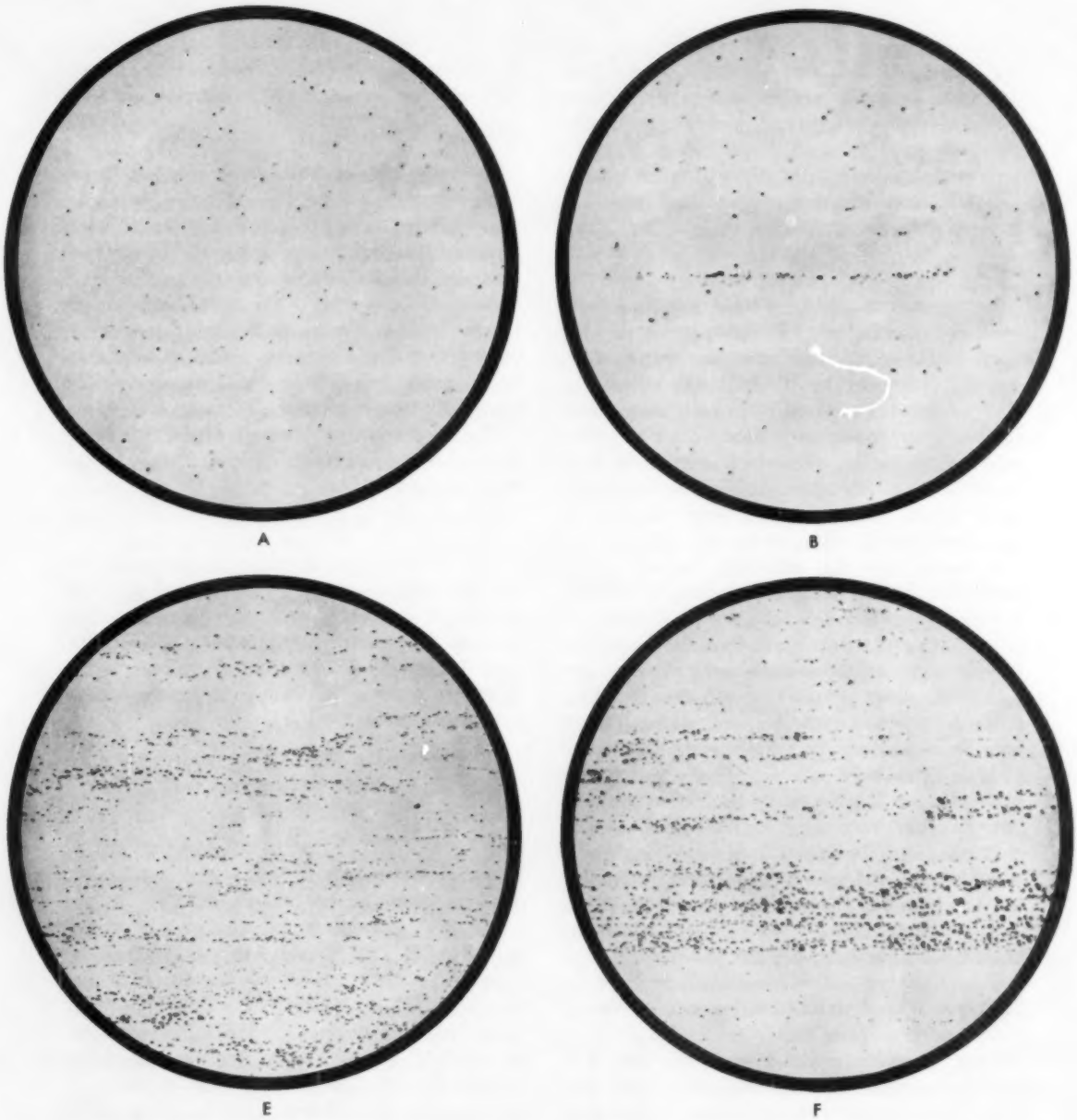
The 75 refers to the maximum length of the largest continuous stringer measured in thousandths of an inch by optical methods. (For 0.400-in. stringer this would be 400.) The alphabetical letter (A in the example) refers to the maximum width of the stringer using the following classification:

A – up to 0.002 in. wide
B – 0.002 to 0.005 in.
C – 0.005 to 0.010 in.
D – over 0.010 in.

The superscript (14) indicates the number of stringers within the counting area.

The B 5 T+ refers to the background as defined by A. S. T. M. (chart 5 in above reference, opposite p. 1650). B shows the shape of the background, T shows that it is a thin series, 5 + shows that it is worse than the 5 illustrated on the A.S.T.M. chart. The A, B, C, and D classifications on this chart are used only to illustrate the shape of the inclusion in this analysis. We do not infer that it governs the composition of the inclusion. The type of material we would like is that having a cleanliness rating similar to D-5. We wish to avoid all stringers typical of the A and C series and minimize those typical of the B series. We have had some heats that would meet these requirements and are working toward a reproducible method to accomplish this end.

On the initial cleanliness rating, take 1-in. long sections from three bars in each heat. Section these so that the longitudinal section passing through the center of the bar can be examined. The ½ sq.in. of area shall be taken with the 1-in. length parallel to the axis of the bar and the



½-in. width in such a location that the worst area of the section is examined. If the rating of any one of these three samples falls below the minimum set up by the temporary standards, six additional samples are taken. If possible, three of six bars shall be the opposite end of the same bars analyzed with the first sampling. No more than three of the nine samples should be below agreed standards for acceptance of the heat.

Frequency/Severity Ratings

This is a modification of the Magnaflux seam inspection method specified by A.S.T.M. Bars are ground and observed under a binocular. The number of seams or stringers are counted and the total weighed value is added to give a frequency over severity rating (F/S). The area examined is a 1-in. diameter surface and a 6-in. length or equivalent area. The ground bars are electropolished and the total number of indications equals the frequency rating. The indications are rated as follows:

⅛ to ¼ in. = 1
¼ to ½ in. = 2
½ to ¾ in. = 4
¾ to 1 in. = 8
1 in. and over = 16

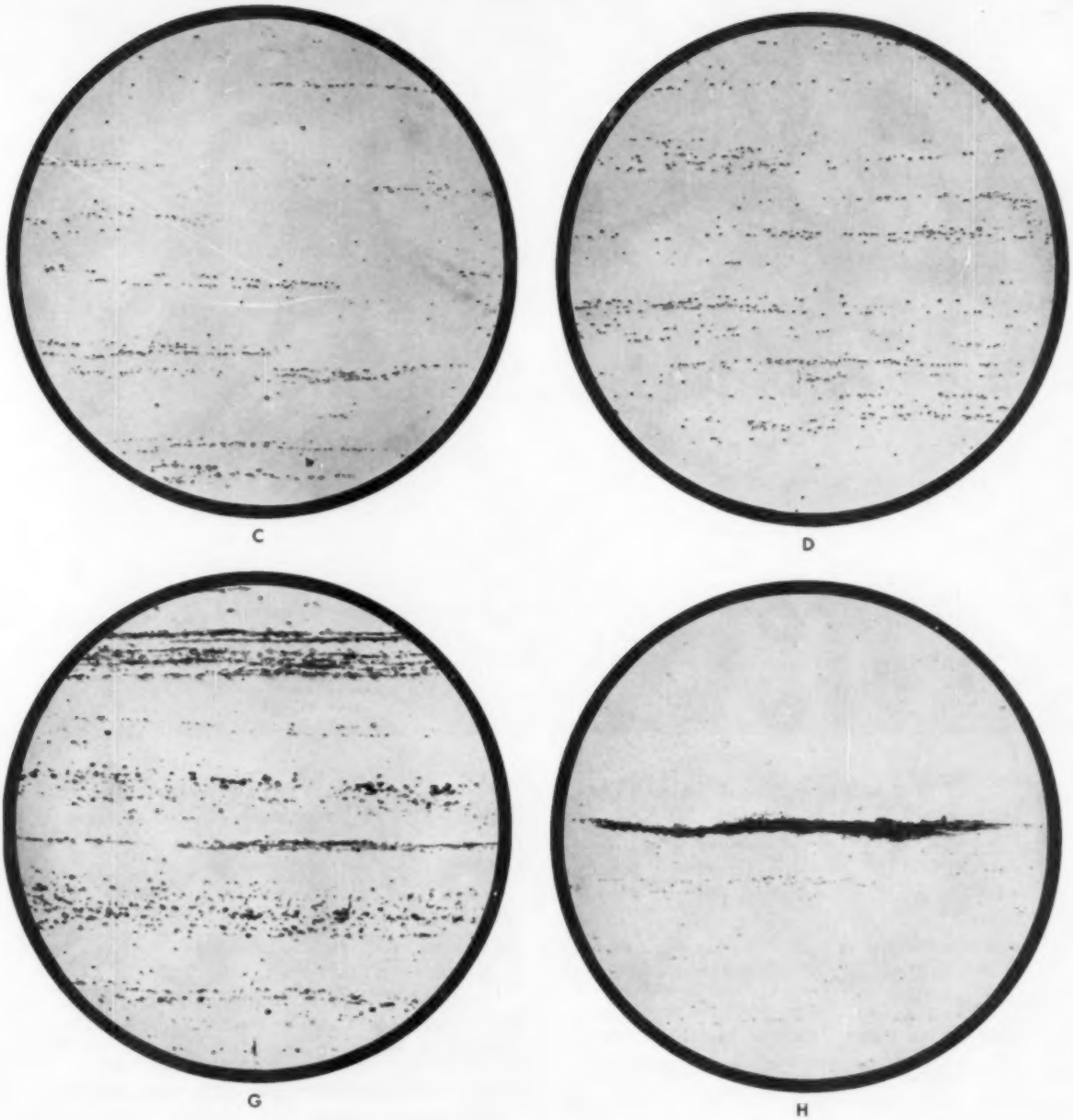


Fig. 2 – Metallographic Classification for Cleanliness of Superalloys. System was developed by Harrisburg, Pa., works of Thompson Products, Inc. 100×

The sum of the weighed values of all indications becomes the severity rating. A rating considered acceptable (temporarily) is F/S not greater than 10/20. Given below are F/S ratings for 11 heats of double vacuum-melted Waspaloy (1¾-in. diameter bars):

Heat No.	Rating	Heat No.	Rating
1	0/0	7	3.0/3.0
2	2.5/6.5	8†	67/120
3*	15.5/39.5	9	0.5/1.0
4	4.5/19.5	10	1.0/1.5
5	0/0	11	2.0/2.5
6	2.5/7.5		

*This heat was borderline. †This heat rejected.

A third evaluation method is to use comparison metallurgical photographs as illustrated in Fig. 2. Our aim is to shoot for material like A of this chart, but we are considering D as borderline acceptable.

This chart evaluates cleanliness on the basis of microstructure only. It was developed by A. McNeillie of the Harrisburg, Pa., plant of Thompson Products, Inc.

Rotor for Low Compression Stages in J-57 Jet Engine, Made of Titanium Alloys. (Courtesy Pratt & Whitney Aircraft)

Why Should I Use Titanium?

*By PAUL M. TYLER**

The inherent advantages of titanium are cited as well as the improvements achieved by alloying. Contrasted with these are some disadvantages largely reflected in difficulties in fabrication. The Sheet Rolling Program is one organized attack to solve some of the latter problems. (A-general, 17-57; Ti)

NOW THAT THE supplies of titanium sponge are ample, satisfactory melting, rolling and heat treating practices are available, strong alloys devised and considerable experience acquired with the metal in fabrication and use, it would be well (in any effort to assess the future) to consider the reasons for using titanium and also some of the shortcomings of the metal and efforts to mitigate them.

Reasons for Using Titanium Metal

Abundance – Titanium ranks ninth in abundance of the elements in the outer crust of the earth. Among metals it is the fourth most common, being exceeded by silicon, aluminum and iron. Furthermore, there are virtually unlimited supplies of titanium ore within continental United States. Many iron ores carry ilmenite ($FeTiO_3$), and the titanium content is normally a nuisance to blast furnace operators, but it may be recovered by proper metallurgical methods. For example, a very large deposit of ore in Quebec contains twice as much ilmenite as hematite and analyzes 21% Ti. It is being smelted at Sorel, Canada, in electric furnaces into pig iron and a high-titanium slag; the latter is an economical source of $TiCl_4$ from which sponge is produced. Hitherto, however, most of the $TiCl_4$ used for the production of metallic titanium in the United States has been made from rutile, TiO_2.

Lightness – Titanium can properly be called a light metal, as indicated by the following specific gravities of the strong alloys:

Magnesium	0.063 to 0.067 lb. per cu.in.
Aluminum	0.10
Titanium	0.16
Alloy steels	0.28 or more
Stainless steel	0.28
Superalloys	0.30 to 0.33
Molybdenum	0.37

It is well known that the ratio of design strength *at working temperature* to the weight of the alloy is a major factor in the choice of material for aeronautics. At room temperature, the strong titanium alloys match the strength of many heat treated alloys and weigh 60% as much. Some aluminum and magnesium alloys can match the strength-for-weight factor and cost much less, but they begin to weaken at tem-

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peratures over 200° F. and soften about 500° F.

The stiffness-to-weight ratio of titanium is likewise high. Its modulus of elasticity is only about 16,000,000 psi. (steel is 29,000,000) but rectangular beams of constant width and equal weight will be over 2½ times as resistant to bending, and I-beams of equal stiffness weigh only 71% as much when made of titanium instead of steel.

Heat Resistance – The melting point of titanium (3035° F.) is higher than that of any other structural metal, but the strength of the pure metal drops rapidly above about 800° F. Alloying elements may raise the useful range up to perhaps 1000° F. Absorption of oxygen and nitrogen causes rapid embrittlement at 1300° F. An allotropic change from alpha (close-packed hexagonal) to beta (body-centered cubic) crystal structure occurs at 1620° F.

The coefficient of thermal conductivity is much lower than that of aluminum, carbon steel, magnesium or copper and compares with that of austenitic stainless steel. The specific heat is about the same as for stainless steel but the thermal expansion coefficient is only half. The heat of vaporization is high.

Corrosion Resistance – Major civilian uses for titanium may be found in chemical equipment; it resists corrosion and erosion in a variety of chemical environments and outlasts many other "corrosion resistant" metals 10, 20, or even 50 times. It is virtually immune to sea water and may be favorably used in marine engines and miscellaneous shipboard applications. Military items can be stored indefinitely without deterioration and without expensive protection. A protective film of stable oxide is probably responsible for the corrosion resistance which may be enhanced by oxidizing agents or by aeration of the corrosive medium.

Miscellaneous – Titanium possesses excellent ballistic properties for its weight and thus is suitable for airborne armored vehicles and for helmets. Its resistance to cavitation and to fluid erosion in turbine blades is good. Fatigue properties are good.

Creep characteristics of the unalloyed metal are too poor for its use in fully annealed condition if loaded close to the yield strength. Creep behavior, however, is greatly improved by cold working. Titanium *alloys* are known to have good creep properties.

Electrical resistivity is exceedingly high for a pure metal.

Cracks do not propagate as rapidly through unalloyed titanium as through aluminum or steels. Next, we discuss unfavorable factors.

Casting – Due to the great affinity of hot titanium for gases and ordinary refractories, melting has always posed serious problems. Titanium ingots are therefore made in a vacuum by arc melting a consumable electrode into a cold mold crucible (usually water cooled copper). The electrode is compacted of sponge and scrap titanium. Only a portion of the melt is liquid at any one time. All ingots are melted twice to assure homogenity and to improve the yield.

Although shaped castings of usable quality are now available, they have been made mostly in machined graphite molds which are relatively expensive and are reusable only 20 to 30 times. Until a suitable expendable mold material is perfected (perhaps powdered graphite), commercial castings are almost out of the picture. This is unfortunate. Large-scale utilization of other light metals began with castings; only lately did the tonnage of wrought aluminum or magnesium products predominate. Recent research by the Bureau of Mines and Du Pont is promising, especially the Du Pont work on expendable mold compositions and alloys with tensile strength of 140,000 psi. as cast. However, if titanium cannot be cast economically, its use may be restricted mainly to simpler forms – sheet, bars, forgings, and extrusions – thus postponing the volume market needed to bring down prices.

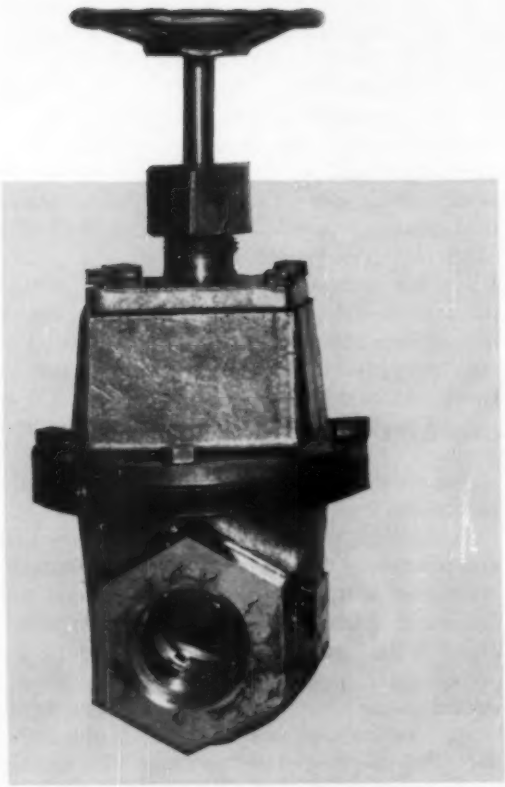
Screen for Food Pulping Machine; Titanium Sheet Perforated With 225 Tiny Holes per Sq. In. (Courtesy E. I. du Pont de Nemours & Co.)

Wear – The metal has quite undesirable frictional and wear characteristics. It tends to seize and gall – that is to say, rub off against another material so that in any sliding or rolling contact, titanium actually rubs against titanium. For example, titanium gear teeth meshed against titanium may have very poor life. Even when meshed against a steel gear, titanium gears have a high coefficient of friction and the surfaces do not readily retain an ordinary oil film.

Titanium, however, can be extruded better than steel; the billets are heated to between 1700 and 1900° F.; the most common lubricants are grease, solid mixtures and molten glass.

Machinability – The Steering Committee for Titanium Research found that most companies considered titanium alloys as easy to machine as the commercial stainless steels. A recent survey found a machine ratio of 1.5:1 for Ti-6Al-4V alloy compared with aluminum, and 1.9:1 for 4340 steel versus aluminum (identical operations). With the exceptions of welding, brazing, and heat treating, fabrication of titanium alloys gives metalworking plants no more trouble than alternatives. The aircraft industry is now reconciled to the fact that the next generation of aircraft will be built largely of hard-to-form materials. In short, the Steering Committee found that industry is willing to accept or reject titanium purely on the basis of its properties, as compared to those of competitive materials, except in certain rather specialized operations such as drilling blind or small holes, and grinding.

Heat Treatment – Although protective coatings, faster working times, and other special techniques are being perfected, high-vacuum equipment or inert-gas shielding is generally needed to avoid contamination not only in melting but in all operations where the metal is welded, heat treated, or worked at temperatures above a carefully controlled maximum. In extrusions, the lubricant may afford protection.



1½-In. Gate Valve; Titanium Castings Made by U. S. Bureau of Mines, Albany (Ore.) Station

Another barrier which research is seeking to hurdle is the temperature limitation which may exclude titanium from future engine systems where higher and higher temperatures are encountered in most sections. There is reason to hope that new titanium alloys will extend the range of usefulness, perhaps to above 1000° F., but the newer iron alloys are likely to remain supreme in the field of higher temperatures.

Welding – As remarked above, welding is done under inert gases – for example, in gas bags filled with argon. Titanium alloys suitable for high-strength applications can be welded, but not with the ease required to make the sandwich panels from thin gage sheet and foil now being specified for more and more fuselage parts to serve under extreme conditions of heat, vibration and sound. Research may solve this problem, possibly by brazing alloys which have flow temperatures low enough to avoid impairing the properties of the heat treated components. Wide thin sheets of desirable dimension have so far been unavailable for sandwich construction, either in titanium or truly competitive stainless steels.

The preceding paragraphs foreshadow the necessary investigations to improve the advantages and remove the limitations. Nothing so far has been said about cost of sponge or of mill shapes, a topic which will be considered at some length in the final article in this series. Mill products still cost far too much per pound to encourage wide use even in places where they are inherently superior. Standard of quality and uniformity compare favorably with competitive materials; knowledge of properties is reasonably complete. New alloys enhance the usefulness of titanium over a wider range of temperatures and applications, and fabrication difficulties have been reduced to tolerable proportions. Research expenditures have been boosted to a record total, estimated at $10,000,000 annually.

Government-sponsored research has included 26 major technological categories. During fiscal year 1957, a little over one-third of the Department of Defense's research on titanium was devoted to physical metallurgy – mainly work on alloy development, effects of interstitials, and transformations. Another third was spent on processing – mostly on welding and joining, with smaller amounts of heat treatment, finishing and coating. The Office of Naval Research also studied the physical metallurgy of extractive metallurgy. The remainder of the research funds were devoted principally to the determination of design data.

In addition to the aims of the sheet rolling program described below, the following desirable objectives have been listed by the Army:

1. High-strength thin-wall tubing in alloy grades with surface finish usable without machining being needed.

2. Alloys hardenable in thicknesses greater than 2 in. while maintaining good ductility and toughness.

3. Satisfactory welding properties or procedures for all high-strength alloys.

Titanium Sheet Rolling Program

High-strength sheet suitable for airframe applications is a major requirement. Phase I of this development (preparation of the sheet material) is largely covered by the Navy's $3,500,000 allocation to the so-called sheet rolling program. Larger sums are being provided by Air Force and Navy for Phase II (determination of complete design data) and Phase III (experimental evaluation in aircraft components).

The sheet rolling program started in April 1956 and is coordinated by the Navy Bureau of Aeronautics and supported by various Navy Bureaus

and by the manufacturing methods branch (Air Materiel Command) of the Air Force. The National Academy of Sciences, through a panel in its Materials Advisory Board, follows progress and provides guidance to insure that the program is "continuously keyed to the urgent requirements of industry and coordinated with industry and related military programs".

Initial objections were defined as follows:

Phase I—To develop optimum techniques for producing sheet alloys possessing adequate uniformity, reliability, strength, fabricability, and elevated-temperature characteristics, and the following ultimate strengths at room temperature: 120,000 psi. max. in the annealed condition and 180,000 psi. min. when heat treated.

Phase II — To develop design engineering data required for use of these new titanium alloys in military equipment.

Phase III — To enable manufacturers of military equipment to evaluate their reliability, fabricability, and serviceability in production quantities and to establish necessary manufacturing data.

Phase I includes contracts with titanium producers to make each of the several candidate alloys in 36 × 96-in. sheets in five thicknesses, ranging from 0.020 to 0.125 in. The effect of the following factors on properties, uniformity and quality of the sheets are to be studied: (*a*) sponge hardness or composition, (*b*) ingot characteristics, (*c*) mill processing, (*d*) surface treatment, (*e*) heat treating operations and (*f*) flattening and finishing operations.

When the program began, the titanium sheet alloys used in production were all of the 110,000-psi. yield strength class, and were used in the annealed and stabilized condition. Present alloys, with improved heat treating practices, may produce sheets with 200,000 psi. ultimate strength at 70° F. with useful ductility, and short-time strengths more than 150,000 psi. up to 700 to 800° F. For short life, as in missiles, new alloys have high tensile strength up to 1400° F., although creep properties are relatively poor above about 600° F.

By the spring of 1957, substantial progress had been made in producing full-sized sheets of four candidate alloys in gages and conditions suitable for airframe manufacture and for developing design data. Within the next 12 months thereafter, the target properties had been attained with three alloys (6Al-4V, 4Al-3Mo-1V, and 2.5 Al-16V). The fourth candidate alloy (3Al-6Mo) was dropped from the program as not showing sufficient promise of being superior to the other three alloys. A new beta alloy (Crucible's B-120 VCA, typically 4 Al-11 Cr-13 V), not yet in this program, has 16% higher strength at room temperature than the target figures.

Sufficient data have been accumulated on a production basis so that alpha-beta alloys can be offered for sale with a guarantee of minimum heat treated properties. By June of 1957 titanium fabricators could set up tentative procedures for making high-strength, heat treated parts from titanium sheet. Alpha-beta alloys and all beta alloys which can be heat treated to high strength can probably be rolled down to sheet 0.002 to 0.125 in. thick, but all alpha alloys are not expected to be readily rolled to the thin gages.

The present status of the sheet rolling program can be briefly summarized as follows:

Commercial procedures for ingot production and hot rolling have been established. Suitable criteria for heat treatment of finished sheets and fabricated parts have also been determined. However, commercial processes for achieving the optimum results of heat treatment as demonstrated in the laboratory, and satisfactory methods for commercial flattening and finishing the hot rolled sheets need further study. These matters are being actively investigated for all three alloys noted in the fourth paragraph above.

Sometime after the sheet rolling program was well under way, additional needs were foreseen — two of them especially urgent: (*a*) a weldable sheet alloy of high strength with creep resistance at 800° F. and over, and (*b*) higher strength, heat treatable sheet. The first combination of properties seems to be incompatible in titanium alloys. Most weldable alloys do not possess high strength when hot, and the maximum temperature for good creep strength seems to be 750° F. for alpha-beta alloys and 950 to 1000° F. for the improved alpha alloys. There is no indication as yet of a titanium-rich alloy suitable for lengthy service at 1200° F.

Conclusion

With information given in the first article in this series about the present ability of the American industry to produce as much titanium and its alloys as can now be used, and the account in this article about the metal's inherent advantages, its eccentricities and difficulties, and the campaign to remove and circumvent them, the groundwork is laid for the last article of the series which will describe the actual uses of the metal and the chances of lower prices with corresponding expansion of consumption.

Book Review

Problems of the Dislocation Specialist

*Reviewed by PAUL A. FLINN**

DISLOCATIONS AND MECHANICAL PROPERTIES OF CRYSTALS, edited by J. C. Fisher, W. G. Johnston, R. Thompson and T. Vreeland, Jr., John Wiley and Sons, Inc., New York, 1958. 634 p. $15.

A METALLURGIST seeking a comprehensive survey of recent developments in dislocation theory may be misled by the title of this book and the dust jacket statement into believing it to be a work of the same sort as the ⊜ Seminar series; it definitely is not. It is mainly an edited version of the papers presented at a small closed conference, held at Lake Placid, N.Y., Sept. 6 through 8, 1956, attended by "fifty-four of the world's leading authorities in the field". The small invited list naturally resulted in limited areas of discussion, so that many important parts of the field – for example, creep and brittle fracture – were essentially untouched.

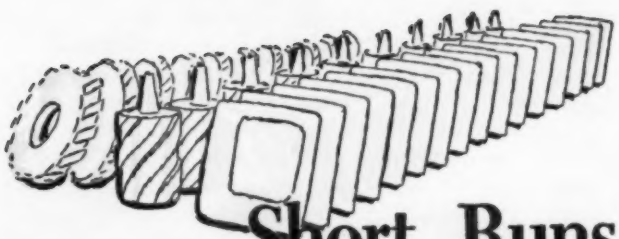
The complete absence of any nonspecialist audience made pedagogic simplification unnecessary, so that the papers are for the most part devoted to controversial matters primarily of interest to those working at the frontiers of the subject. A thorough background in the field is essential for understanding most of them.

The emphasis on unsolved problems may lead the unwary to underestimate the amount of well-established theory in this field. Some notable exceptions are present, which are of quite general interest. Some of the papers in the first section of the book should be a revelation to anyone who still regards dislocations as fragments from a physicist's nightmare. Dislocations in a variety of materials are shown in an extensive series of beautifully reproduced photographs. These pictures confirm in amazing detail the predictions of the theorists. Especially notable are the pictures of decorated dislocations in silicon, showing dislocation sources looking almost exactly like the textbook drawings based on the theories of Frank and Read. The clearest observations are those on transparent materials, such as the alkali halides and silicon (transparent in the infrared), but work on silver and aluminum confirms the belief that the same essential features are present in both metals and nonmetals.

Also of general interest is the long paper (87 pages) by Seeger, "The Mechanism of Glide and Work Hardening in Face-Centered Cubic and Hexagonal Close-Packed Metals". This paper represents a considerable extension of the talk given at the conference, and includes sufficient background material to make it intelligible to nonspecialists. The discussions and illustrations of stacking faults and extended dislocations are exceptionally clear.

The other sections of the book ("Deformation of Pure Single Crystals", "Work Hardening and Recovery", "Alloy Crystals", "Impurities", "Yield Point Phenomena", "Dislocation Damping and Fatigue", "Theory of Dislocations", "Whiskers and Thin Crystals", and "Radiation Damage") will be of interest principally to specialists concerned with current controversies, since, with the exception of the paper by Seeger mentioned above, the papers are mainly concerned with the details of unsolved problems. ⊜

*Advisory Engineer, Research Laboratories, Westinghouse Electric Corp., Pittsburgh.



Short Runs...

Titanium in Nodular Cast Iron

*By A. TOMINAGA, I. AOKI and T. TOTTORI**

THE FORMATION of graphite nodules in ductile cast iron is known to be adversely affected by titanium, arsenic, tin, lead, bismuth and antimony. Each has been investigated separately in magnesium-treated melts; the effect of elemental combinations, however, was unknown.

To investigate the cooperative influence of these tramp elements, six small heats of iron with varying amounts of titanium were made. Samples from each heat were melted. After adding arsenic, tin, lead, or bismuth to the melt, they were treated with magnesium and cast. The structures were examined microscopically to ascertain the effect of the various additions.

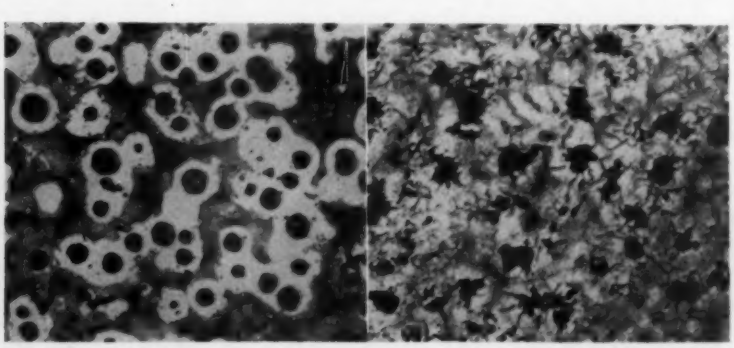
*Laboratory Director, Laboratory Staff Engineer and Laboratory Engineer, Respectively, Fuji Iron and Steel Co., Kamaishi Works, Kamaishi City, Japan.

Titanium by itself is no obstacle to the formation of graphite nodules; however, when it is in combination with any of the other elements listed, nodule formation is inhibited. Bismuth has the most detrimental effect; as little as 0.0005% in an 0.08% Ti iron will block the formation of nodules. In decreasing order of damage, the elements are lead, antimony, arsenic and tin.

Vacuum Furnace for 3000° F.

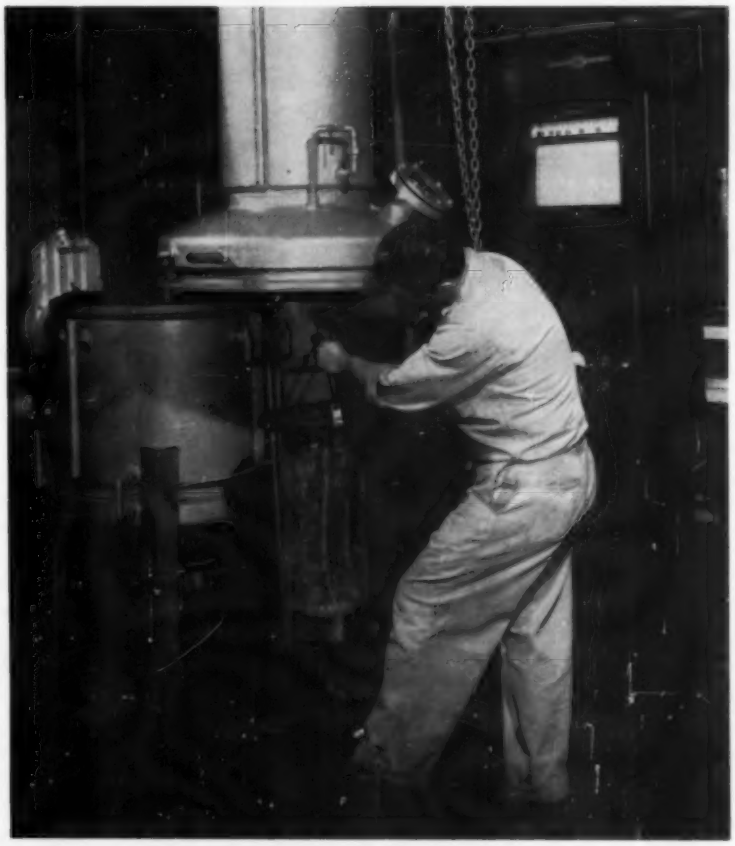
The operator in the photograph opposite is removing a load of parts from a vacuum furnace which operates at 0.1 micron pressure up to 3000° F. Developed by C. I. Hayes, Inc., Cranston, R. I., the furnace has been in operation in the Hayes plant on a variety of production parts for the past year.

Furnace Details – A new heating element design is used in place of refractory-supported spiral coils. Heating elements are made of



Effect of Combined Titanium and Antimony on Nodule Formation. Left – 0.071% Ti, 0.0026% Sb; right – 0.094% Ti, 0.031% Sb

A Batch of Bright Ni-Span-C Diaphragms Is Removed From the Cooling Chamber of Vacuum Furnace After Precipitation Hardening



shaped plates of molybdenum. The cross-sectional area of the element allows the voltage to be reduced to a low value, and a high watt-density is achieved by raising the amperage correspondingly. Heating elements appear bright and shiny after use. The entire furnace chamber is made of nickel-clad steel and is surrounded by a circulating water jacket (making it a "cold-wall" furnace) to eliminate the need for a hot-wall refractory lining.

Cylindrical radiation shields, constructed of molybdenum, are used for maximum heat focusing efficiency. They keep heat from radiating too rapidly into the surrounding water jacket. The furnace (it will handle a loading tray 8½ in. in diameter by 15 ft. long) will reach 3000° F. in less than 30 min. after pump-down.

Vacuum System – A mechanical roughing pump quickly reduces pressure to about 100 microns, after which a booster pump and diffusion pump are cut in to produce a fine vacuum. The entire cycle requires some 15 min. to reach full vacuum.

After treatment is completed, the work is raised to the cooling chamber located directly above the baffled heating chamber. Here, heat radiates rapidly into the water jacket, which is kept close to the work for highest cooling efficiency. Temperature of parts falls from 3000° F. to below 700° F. in less than 30 min.

Applications – Titanium, tantalum, tungsten, molybdenum, zirconium, hafnium and columbium have been heat treated with no discoloration. The furnace is being used in the Hayes plant for annealing and degassing tantalum sheet on a contract basis. This requires treatment at about 2600° F. Tantalum must be cooled under vacuum to below 200° F. after degassing to prevent its picking up gas again from the atmosphere during cooling.

A high-temperature alloy part used in jet engines is brazed at 2150° F., then diffused at 2050° F. and finally annealed at 2250° F. – all without removing it from the furnace and with almost immediate temperature changes after each stage. Another application being looked into is sintering molybdenum above 2800° F. on a production basis.

Staff Report

Metal Problems Considered at A.S.T.M. Meeting

TWO RATHER DIFFERENT VIEWPOINTS of the metallurgical future were taken by leading speakers at the annual meeting of the American Society for Testing Materials in Boston, late in June. Clyde Williams, recently retired president of Battelle Memorial Institute, took an optimistic view of the future supply of refractory metals and our ability to solve the problems of high-temperature use in his presentation of the Gillette Memorial lecture. On the other hand, the Marberg lecturer, E. W. Pehrson, chief of the division of foreign activities of the U.S. Bureau of Mines, painted a future dominated by a Russian-Chinese combination based on supremacy in iron and steel production and its related mechanical civilization.

Mr. Williams called attention to the relative youth of the problems of heat resistance, noting that it was first given broad consideration in a joint meeting in 1923 of the American Society for Testing Materials and the American Society of Mechanical Engineers. Yet now it is a critical matter in design and operation of high-speed aircraft and missiles and their power plants. For example, temperatures in afterburners in jet engines approach 4000° F. – a situation undreamed of in 1923, only 35 years ago.

Without minimizing the importance of minor alloying elements, he said that the real work horses in this jet age are six metals – chromium, nickel, cobalt, columbium, molybdenum and tungsten. He presented data on their present annual consumption, their anticipated demand by 1965, and the apparent reserves – unmined ore in the free world. Of these six, nickel and chromium must be depended upon for the real tonnage usages. At present, only a minor percentage goes into high-temperature metals; most of it is used in corrosion resistant alloys. Nevertheless, the total consumption for all purposes will probably triple in the next seven years, and it is fortunate that new nickel deposits are under development in Manitoba and new chromium deposits in Africa, backed up by enormous deposits of iron ore in Cuba from which both metals can be extracted. Molybdenum is *the* American metal. While we now get more than enough tungsten for our needs, the big reserves of ore are in China. Attention to the other two, cobalt and columbium, as basic metals rather than alloying elements, has been so recent that nothing much more than a guess is possible as to the future requirements, and Mr. Williams's guess was in the neighborhood of 10,000 to 15,000 tons per year by 1965.

His optimistic attitude about future supply was apparently based in large measure on past experience. More than once in this century a serious anticipated shortage in some important mineral has been avoided by a governmental guarantee of a firm and high price for new supplies for a number of years. This puts the prospectors into the field, new mines are opened and concentrators built.

To this reporter there are two objections to this line of reasoning. The first is that it takes time – years, in fact – to discover and develop new sources of metals. Too often do we hear talk of the next "emergency" as being a period of three to five years, whereas in actuality it will be all over in as many days or weeks. There will be no time to do anything but fight the next war with what we have ready for instant use.

The next objection was well stated by Mr.

Pehrson in his Marberg lecture – namely, that supplies of minerals (although undoubtedly sufficient for man's needs) are not uniformly distributed geographically. Thus, experience during World War II indicated that there simply isn't enough tin in the Western Hemisphere to supply the United States. In fact, recent events indicate that our hegemony in the Western Hemisphere is somewhat shaky just now!

Mr. Pehrson's charts indicate that the United States is now far from self-sufficient in such important raw materials as iron ore, bauxite, copper, and manganese. Fortunately our good neighbor Canada has sufficient supplies of nickel, lead and zinc to help us out. Russia, in contrast, is almost self-sufficient mineralogically – completely so, in fact, if the adjacent land mass of China is included.

The most arresting portion of his talk stemmed from a reminder that, since the beginning of the industrial era, the supremacy of a nation or group of nations depends on its supply of iron ore and coking coal – that is to say, its iron and steel industry. First was England, then the Ruhr region, now the United States. However, the Sino-Soviet bloc has larger resources of iron ore and coking coal than America. They have the necessary raw materials, and current production statistics show they have the necessary intelligence to utilize them. Furthermore, such a large proportion of their output goes into munitions and heavy industry that the rapid emergence of a new and ruthless leader in the economic world is foreshadowed.

Another interesting comparison: Although there are ample supplies of rich iron ores in Russia, much of their metal is gained from the leaner deposits. In contrast, American importation of foreign ore is sharply rising; our industry apparently has concluded that it is cheaper to import high-grade than to concentrate or smelt our low-grade ores. Mr. Pehrson believes that in this respect it would be sound national policy to be completely self-sufficient – a conclusion with which this reporter heartily concurs.

High-Temperature Alloys

A rather large amount of attention was given to testing methods, new testing machines, and new metallic combinations in the field of elevated-temperature use. Since it is so difficult to translate information gained by rotating beam and creep tests on round specimens to the design of a turbine bucket, for example, P. E. Hawkes and C. H. Ek of General Motors Research Laboratory devised a machine which tests a hot sample cut from thin sheet under combined tension and rapid flexure – thus simulating fairly closely the conditions existing in a gas turbine.

Metals for specific uses certainly must have strange combinations of qualities. An instance was described by G. F. Weissman and W. Babington of Bell Telephone Laboratories. They needed a small but complicated mounting for the main guidance system of the Nike Hercules missile. Magnesium alloy was indicated for its lightness and strength, but the standard casting alloy AZ 81 A did not have sufficient damping capacity to prevent trouble from resonant vibrations and there was not enough room to build shock-absorbing mounts into the equipment. So – nothing to do but devise a new alloy (it turned out to be magnesium plus 0.65% zirconium and has been nicknamed K-1-X-1), castable either in sand or dies, with good shock resistance and safe under impulses up to 2000 cycles per sec.

Finally, as an indication of the trend in high-temperature materials, may be cited a paper by Walter S. Cremens and Nicholas J. Grant of Massachusetts Institute of Technology. They find that the strikingly good properties of "SAP" (sintered aluminum powder containing considerable oxide) are also evident in a similar mixture of nickel and about 15% by volume of Al_2O_3. Unusual high-temperature strength and structural stability are due to the quasi precipitation hardening effect of the insoluble oxide and to its interference with the tendency toward grain growth at elevated temperatures.

The experiments were made by mixing the finest powders available, which were 2 microns average grain size for the nickel and 0.02 micron for the oxide. These were blended dry, placed in a rubber sack, compacted into bars under 75,000 psi. hydrostatic pressure, machined, canned in steel, and extruded at 1950° F. Diametral reduction was about 25 to 1 into a bar about ¼ in. diameter and 3 ft. long. Rupture-life tests at 1500° F. show that the best results come from pieces with the smallest grain size or interparticle spacing and the most uniform distribution of particles. Eventually this optimum condition will probably be achieved by making an alloy of nickel with about 2% aluminum, manufacturing the part, and then heat treating it in an atmosphere so controlled as to oxidize the dispersed aluminum throughout the body of the piece. E.E.T.

More on A.S.T.M. Meeting

Staff Report

Inclusions: Nuclei for Fatigue Cracks?

WHAT EFFECT do inclusions have on fatigue life of steel? A technical session at the A.S.T.M. meeting sheds some new light on this question.

In discussing the results of tests on 309 specimens* of aircraft-quality S.A.E. 4340 and 4350 steels in the tensile strength range of 140,000 to 300,000 psi., F. B. Stulen, assistant chief engineer, Curtiss-Wright Corp., Propeller Div., Caldwell, N.J., concluded that long-life fatigue strength depends not only on the inclusion size but also on the hardness level of the steel. (H. N. Cummings, consulting engineer, and W. C. Schulte, chief metallurgist, were coauthors of the Curtiss-Wright report.) The study was concerned with electric furnace steels, made so that the dominant inclusions are the silicate type having more or less spheroidal shape as shown in Fig. 1.

Specimens with minimum diameter of 0.230 in. and finished to rms. of 2 to 5 micro-in. were tested in an R. R. Moore rotating-beam machine at 10,000 at 12,000 rpm. Mr. Stulen reported that practically all cracks leading to fracture originated at small microscopic inclusions of the silicate type which were located at, or very close to, the surface of the specimen.

Fracture surfaces were examined at a magnification of about 400 ×, in polarized light, and inclusions nucleating the failures were measured by use of a micrometer eyepiece. Since the inclusions were more or less spheroidal, measurements were made parallel to and perpendicular to the surface. The geometric mean diameter (GMD) – that is, the square root of the product of length and depth – was used as the characteristic size of the inclusion.

*Actually several thousand specimens of S.A.E. 4340 and 4350 steels were tested in this investigation made for the Air Force program. The data reported were obtained from 309 of the specimens which were run at stress levels near the endurance limit.

Figure 2 shows the average fatigue strength for specimens having inclusions of various sizes at origin of failure for steels with increasing tensile strengths. Conclusions drawn by Mr. Stulen can be summarized as follows:

1. The medium and long-life fatigue strength of the steels decreases substantially for each 0.001-in. increase in the size of the inclusions, particularly at the high hardness levels.

2. The fatigue strength reduction factor of an inclusion of given size generally increases as the hardness of the steel increases. However, at hardness levels below about 140,000 psi. ultimate tensile strength, inclusions of the sizes found are probably not serious stress-raisers.

3. There is reason to suspect that a steel having no inclusion larger than about 0.00025 in. is in effect an "inclusion-free" steel, or at least a steel in which the effect of inclusions is insignificant. This is based partly on the fact that no inclusion smaller than 0.00024 in. GMD has been found in the nucleus of single-origin fractures.

4. The mathematical theory of elasticity cannot account for the variations in the notch reduction factor because of inclusions. The sensitivity of inclusions at high hardness levels may be associated with high residual tensile stresses around the inclusions which are caused by differential thermal contraction during heat treating.

In elaborating on the last point, Mr. Stulen noted that the classical mathematical theory of elasticity would not predict a change in the notch reduction factor (or stress concentration factor) when the hardness of the material is changed. Another point he made: The stress concentration factor of a discontinuity, according to the classical theory, is not affected by the size of the discontinuity, provided it is small in relation to the size of the cross section. In other words, he emphasized, "according to these theories, the notch reduction factor for a given type of inclusion should be constant regardless

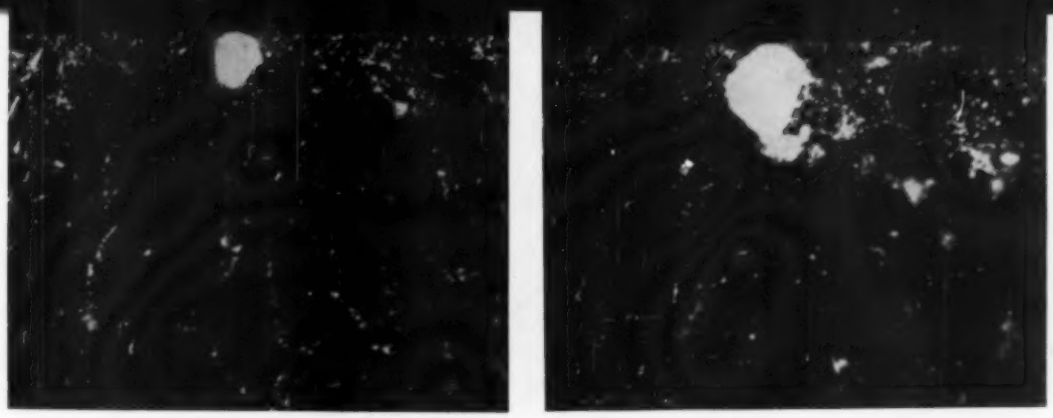


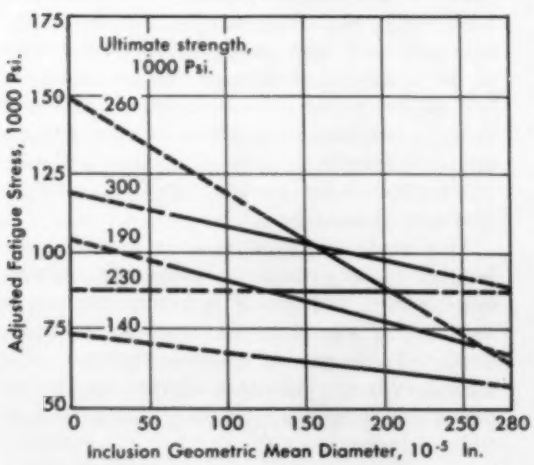
Fig. 1 – Typical Inclusions Which Were Found at the Origin of Fatigue Failures in S.A.E. 4340, Heat Treated to 140,000 Psi. Specimens were tested at 86,000 psi. The one on the right (with larger inclusion) failed after 263,000 cycles while the one on the left (with smaller inclusion) withstood 486,000 cycles. 300 ×. (Courtesy Curtiss-Wright Corp.)

of its size and the hardness of the material".

Several hypotheses were advanced to explain these discrepancies. The effect of hardness on sensitivity to an inclusion of a given size may be caused by lack of sufficient ductility to allow yielding and consequent stress alleviation in the high-stress region about the inclusion. Or it may be caused by residual tensile stresses around the inclusion, set up during cooling in the heat treat operations.

Mr. Stulen stated that as a result of the Curtiss-Wright studies the Air Force is sponsoring research to develop methods for making steel free of silicate inclusions. One heat produced in this program gave the highest fatigue strength ever reached by any metal.

Fig. 2 – Average Fatigue Strength for the "Endurance Limit" of Smooth 4340 Specimens (Except 300,000 Psi. Which is 4350) Having Inclusions of Various Sizes at Origin of Failure. Solid lines show range of actual tests; dotted lines are extrapolated. R. R. Moore Rotating-Beam test. (Courtesy Curtiss-Wright Corp.)



Work on High-Carbon Steel Wire

Work reported by Harry C. Burnett, National Bureau of Standards, showed that the torsional fatigue life of cold drawn music wire is decreased by the presence of inclusions. Tests compared a commercial drawn wire with wire from a vacuum melted heat.

Mr. Burnett pointed out that small-diameter wire for springs is commonly specified on the basis of tensile strength. Previous work at the National Bureau of Standards and elsewhere has indicated that this is not an adequate criterion of the fatigue behavior of the wire under the torsional load to which it is subjected in helical extension or compression springs.

Previous work at the Bureau has shown that in helical compression springs coiled from cold drawn wire the initial fatigue cracks are parallel to the longitudinal axis of the wire and coincide with a plane of maximum shear stress. Stringer-type inclusions in wire are drawn out parallel to the axis of the wire so that if such inclusions were eliminated the fatigue properties of springs coiled from the wire would be improved. To test this a heat of vacuum melted steel was secured with a composition similar to commercial cold drawn wire and oil tempered wire. A machine was designed to determine the torsional fatigue properties of wire without the need for coiling it into springs. The results of the fatigue tests are given in Fig. 3, including studies of the effect of shot peening.

Mr. Burnett noted that cold drawn wire has a greater tendency to develop longitudinal fatigue cracks than oil tempered wire, making it difficult to compare the two types. Inclusions (which are drawn out with the wire) decrease the torsional fatigue life of cold drawn wire.

The reversed torsional fatigue strength of wire at high stress amplitudes is greatly increased by

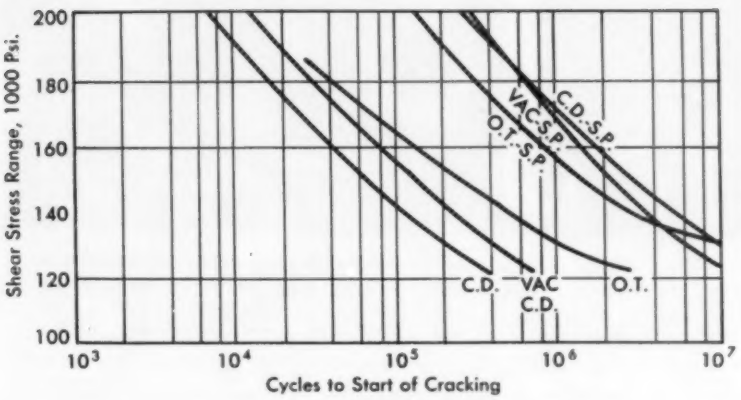


Fig. 3—Fatigue Tests on Springs Coiled from Cold Drawn Music Wire (CD), Oil Tempered Wire (OT) and Vacuum Melted High-Carbon Steel (VAC). Included are results of tests on similar springs in the shot-peened (SP) condition. (Courtesy National Bureau of Standards)

shot-peening. When accompanied by stress-relief, it significantly improves the pulsating fatigue strength of springs coiled from small-diameter wire. Springs coiled from wire as small as 0.039 in. in diameter were successfully peened with shot 0.009 in. in diameter.

Mr. Burnett recommended shot-peening followed by stress-relief at 450° F. However, he emphasized that spring design must allow for adequate penetration of shot between adjacent coils to give peening of the inner surfaces.

Effect of Grinding and Tumbling

It has generally been assumed that parts ground transversely to the direction of applied stress would have a lower fatigue limit than those ground parallel to it. No such effect was found for two different grinding conditions, L. P. Tarasov, Norton Co., reported. Changing the grinding direction from longitudinal to transverse relative to the length of the bar either left the fatigue limit the same or increased it by about 10%.

The fatigue limit was increased when soluble oil was used under grinding conditions representative of good commercial practice. The surface stress changed from tensile to compressive when the grinding direction was made transverse instead of longitudinal and the location of failures changed from surface to subsurface.

Mr. Tarasov stated that abrasive tumbling of bars ground either with grinding oil or soluble oil gave very high compressive surface stresses. All failures nucleated below the surface, and fatigue limits were raised 12,000 psi. above those for the corresponding ground conditions.

However, he noted that fatigue limits for tumbled bars could not be correlated with surface stresses. This indicates that the cold worked conditions of the surface can also affect the fatigue properties, as was found to be true with grinding.

These results are based on reverse-bending fatigue limits obtained for flat bars made from modified A.I.S.I. 52100 steel, uniformly hardened to Rockwell C-59 and substantially free from residual stresses.

Distribution of Fatigue Failures

W. S. Hyler, Battelle Memorial Institute, reported on tests made on the same steel to study the locations of fatigue nuclei in flat hardened steel bars in cantilever bending. Results showed that the mean longitudinal fracture location was near the maximum stress section and that the location was relatively insensitive to grinding or tumbling conditions, relative stress level (ratio of applied stress to fatigue limit), and whether failure nucleated at or below the surface.

Mr. Hyler reported that the transverse locations of the fatigue nuclei were distributed fairly uniformly along the flat surfaces of the bars with only slight evidence that the corners of the specimens were more frequent sites for fatigue nucleation. He also stated that some grinding conditions and all tumbling conditions improved fatigue strength. In these cases, fracture nucleation was predominately subsurface—generally at inclusions.

Two kinds of inclusions were found at the fatigue nuclei: complex oxide and titanium cyanonitride. The oxide inclusions were more massive and were found at considerably greater depth. There was no evidence, however, that the larger oxide inclusions affected fatigue behavior differently than did the titanium cyanonitride inclusions. A.G.G.

IRSID Opens Pilot-Plant Laboratories

By our European Consulting Editor

New research station, equipped primarily to study iron ore and hot metal techniques, will operate on tonnages sufficient to extrapolate full-scale methods. (A9j, B-general, D-general; Fe, ST)

THE FRENCH IRON AND STEEL RESEARCH INSTITUTE (Institut de Recherches de la Sidérurgie Francaise, abbreviated as IRSID) has just inaugurated a station for pilot-plant operation at Maizières-les-Metz in Eastern France. IRSID already has operated for many years well-equipped and efficiently staffed laboratories at St. Germain-en-Laye, near Paris, largely occupied with the physical chemistry of steelmaking and the physical metallurgy of the product. Experiments much larger than test-tube scale were performed in the plants of cooperating firms.

The purpose of the new research station is to enable the industrial departments of IRSID to process (outside of cooperating industrial iron and steel works) tonnages sufficient to extrapolate full-scale methods. Present equipment is intended primarily to study iron ore and hot metal techniques.

The plant is built in the southernmost part of Maizières-les-Metz, a small community on the Moselle river about 4½ miles north of Metz and 7 miles south of Thionville, on a 29-acre site provided with railway connections. This location has the advantage of being in the industrial Lorraine basin, close to Luxembourg and the Saar, and in the neighborhood of a big city. Clearing and road building began in 1956 and was completed rapidly enough to allow major construction to be started early in 1957.

The plan on p. 124 shows the present general arrangement. Four buildings are located in the northeast part (two are assigned to ores, one to hot metal, one as a workshop), while in the southwest part are grouped the laboratories, administrative building and staff house.

Ores – The block assigned to ores comprises two adjacent shops, bright and roomy, each equipped with a 10-ton overhead crane of 50-ft. span, and flanked on the western side by a one-story lean-to. The eastern shop is intended for ore dressing, and can crush batches of ore weighing several tons down to grain sizes of 60 to 100 mm. The products, taken up in 3-ton skips, can then be sent either to storage bins (four hoppers of 30-ton capacity), or to the ore dressing devices. The different operations of preparation, drying, crushing, screening and separation can be carried out and studied in continuous circuits having a through-put of several tons per hour. Various prototype devices, in process of development or construction, are installed for the vacuum treatment of finely divided ores.

The western shop of this pair is mainly assigned to devices for beneficiation and agglomeration. The equipment can dress, dry or wet, on a small scale (outputs not exceeding a few hundred pounds per hour). There is also gravimetric and magnetic concentration equipment with outputs up to 5 tons per hr.

The sintering section comprises a large installation including bins of various sizes, and coke testing equipment properly instrumented.

Hot Metal Shop – The shop designed for hot metal work is equipped with a 20-ton overhead crane, of 60-ft. span, with a 5-ton auxiliary hoist, and is flanked by two narrow one-story buildings.

For iron or scrap melting a 6-ton arc furnace has been installed in the center of the shop, on a working platform set 10 ft. above floor level. The furnace has a tilting roof, mechanized charging, and automatic hydraulic electrode adjustment; it can melt a 4-ton charge in less than 1½ hr. (power, 3000 kva.; primary voltage, 5500 v.; eight secondary voltages, ranging from 220 to 87 volts).

Between the unloading platform and the furnace, a concrete block, called the testing area, temporarily accommodates the metallurgical equipment. A system of easily removable wooden floors, on the block, facilitates working conditions around the apparatus. At the time of the inauguration, a 6-ton converter was being assembled in this area.

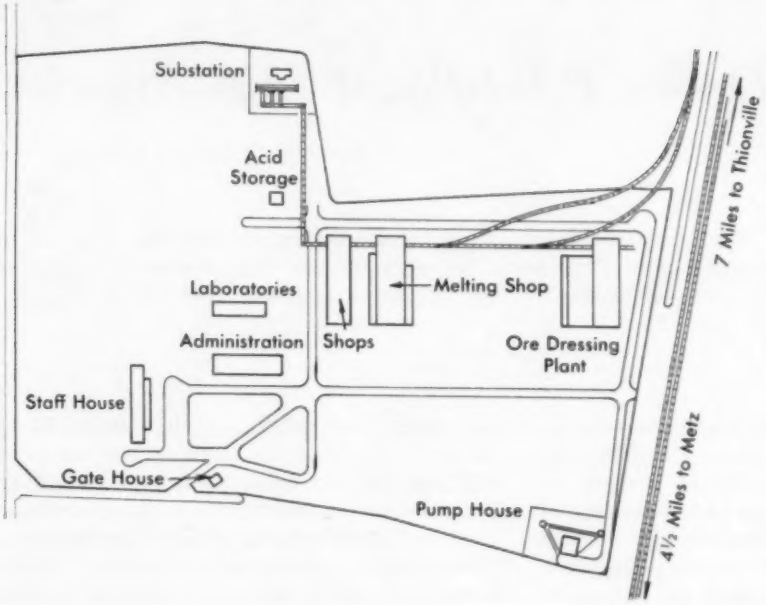


Fig. 1 – IRSID's Plan of New Pilot-Plant Laboratories Near Metz

The western shop houses stockrooms, offices and sanitary installations. At the southern end of that building are installed the high-frequency furnaces which have been transferred from St. Germain-en-Laye (a conventional furnace of 675-lb. capacity, and a vacuum melting furnace of 100-lb. capacity).

Auxiliary equipment includes an 830-hp. compressor for low-pressure blast, a motor-generator set for the high-frequency furnaces, and a 150-hp. air compressor feeding compressed air to the whole plant.

Workshop – This is a single building equipped with a 10-ton overhead crane of 50-ft. span. The essential function of this section is to assure the general maintenance of the pilot plant and to prepare and service the testing and measuring equipment. The central part contains the machine shop, boiler shop, and the electrical maintenance section. Room has been reserved for a testing and assembling platform. The southern part of the shop contains offices and an electronics laboratory.

Services – Electrical power enters through a three-phase 63,000-volt spur from Electricité de France and emergency 5500-volt line from the Sidelor station about 4 miles west. Current is transformed at a substation and power is distributed into the various buildings through 5500-volt underground cables. Three transformers supply 220 and 127-volt current for lighting and small equipment. Gas is obtained from the East Paris grid. All the water needed is supplied by two wells yielding potable water. An automatic station pumps it into a 40,000-gal. ground tank from which it is distributed. Waste water is discharged into a nearby brook after having been purified and neutralized. The shops are heated by means of space heaters called "caloriblocs", supplied by fuel oil, and the other buildings have central heating by hot water.

Laboratories – The laboratories of the pilot plant are intended to carry out all the routine chemical or physical investigations of iron ores, metals and metallurgical products. Fundamental studies are still reserved for the laboratories at St. Germain-en-Laye. On the ground floor are located a large room for sample preparation, a room for separation of iron ores in heavy media ("sink-float"), a chemical laboratory, and stockrooms for chemical products and glassware. Rooms are also reserved for physical measurements. The first floor is, in the main, occupied by a large chemical laboratory with ten workbenches. On either side are a balance room, a room for colorimetry, and offices.

Administration – The administrative building contains most of the offices, library and a museum of geological specimens.

The pilot-plant research station at Maizières-les-Metz has been operating since the beginning of 1958, employing 110 members of IRSID, 28 of whom are trained personnel. Its creation considerably increases the sphere of action of IRSID for the development of new processes. It will also go a long way to strengthening the necessary links between research and industrial production in the French iron and steel industry.

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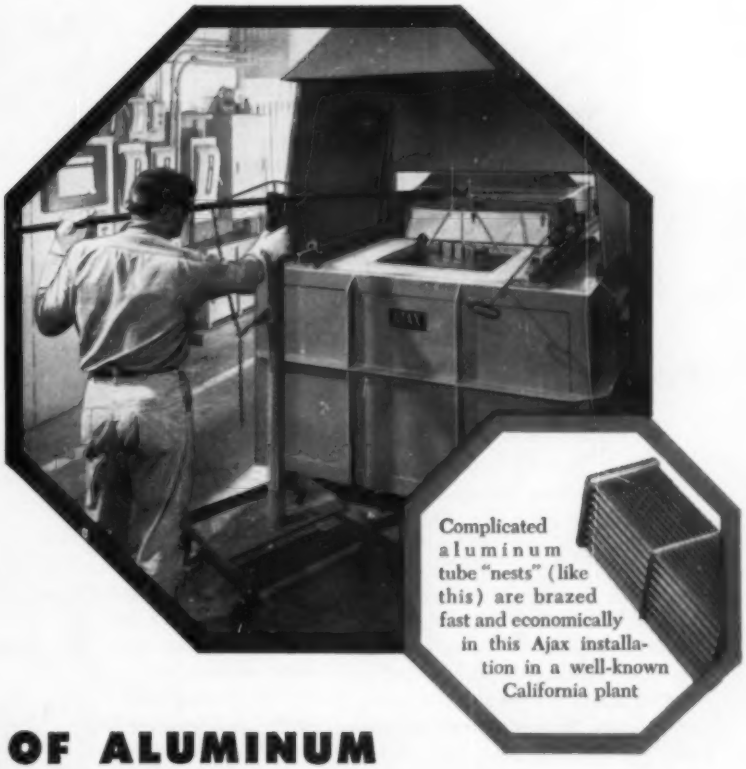

Complicated aluminum tube "nests" (like this) are brazed fast and economically in this Ajax installation in a well-known California plant

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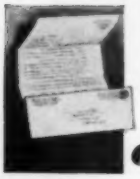

Correspondence

Recrystallized Surfaces of Aluminum Extrusions

NEW KENSINGTON, PA.

In the article on the above subject in *Metal Progress* for December 1957, p. 102, Guy V. Bennett places on record the facts as they pertain to extrusions in alloys 2014 and 2024. Toward the end of his article, he mentions a couple of ways to avoid the low mechanical properties of such surfaces. I would like to expand upon these proposals a little and provide additional information that the aircraft designer and others can use.

A most important step in avoiding the troubles inherent in this recrystallized surface layer is to realize that it exists. Another is to enlist the aid of the metal supplier. If a solution is sought early in the procurement program, it can be obtained with only minor compromises in even the worst situations.

The following data and illustrations point out some of the most likely approaches.

The three photos in Fig. 1 illustrate the change in extent of recrystallization that occurs along the extruded length of a typical spar cap section in alloy 2024. This surface layer can be avoided by scrapping a little more than the usual amount of the rear end of the extruded piece. Since parts machined from extrusions are frequently bigger at one end than the other, it would sometimes be possible to orient the finished part suitably with respect to front and rear of extrusion. In this way, *all* recrystallized material could be removed. This procedure requires consideration of right and left-hand parts.

Perhaps Mr. Bennett's suggestion to avoid the problem by choosing a different alloy is the simplest one. Less coordination is required. Figures 2 and 3 illustrate the very limited extent of recrystallization that occurs with the aluminum-zinc alloys. The most popular of these is 7075 (Fig. 2). Somewhat greater strength is available in alloy 7178. Both of these are for practical purposes free of recrystallized areas that would affect the strength of parts machined from extrusions. Alloy 7079 (Fig. 3) is still in the experimental stage with regard to extrusions; its advantages are greater transverse ductility, higher strength

Fig. 1 – Etched Cross Sections of a Typical Spar Cap Extrusion of 2024 Aluminum Alloy, 2 Ft., 15 Ft., and 30 Ft. From Front, Respectively, Top to Bottom

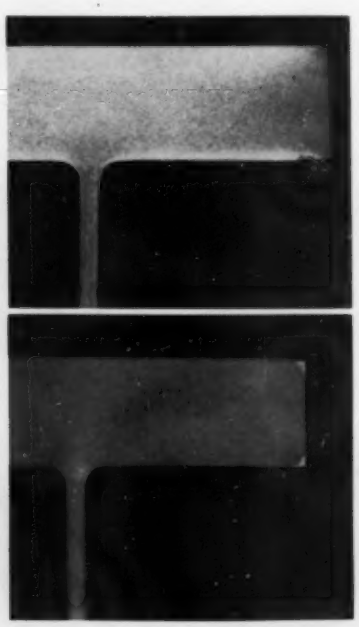

Fig. 2 – 3 × 3-in. H, 7075 Extrusion. No visible recrystallization on surfaces at front end of bar (top section) and very little at corners at the rear end

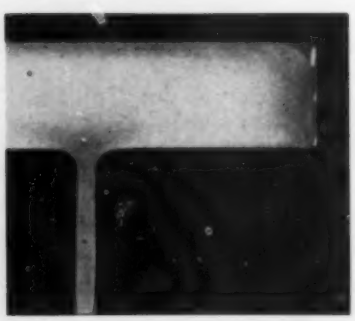

Fig. 3 – Rear End of Same H-Extrusion When Made of Al-Zn Alloy X7079, Showing a Little More Recrystallization at Edges Than 7075 in Fig. 2

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You can now produce melts in vacuum or a controlled atmosphere—in ingots up to 24" diameter and larger—of steel, zirconium, titanium, and high melting point alloys. You can produce melts of very high purity and superior grain structure; for example: titanium with hydrogen levels held to 0.0012 wt.% and Brinell hardness values between 95 and 105.

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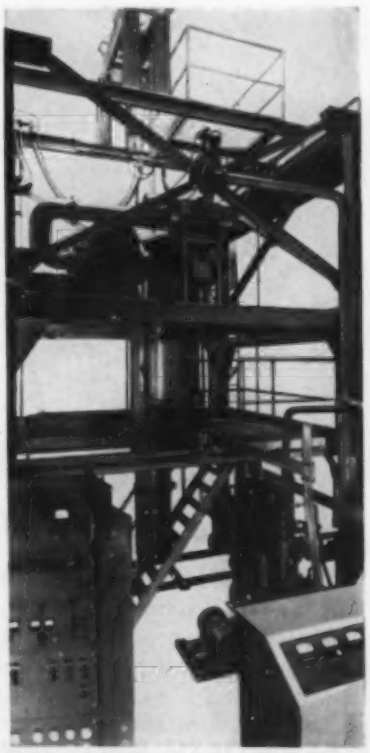
How to purchase. There are five standard models of the Heraeus furnace with capacities from 20 lbs. to 6600 lbs. of steel—and special designs with capacities ranging up to and beyond 10,000 lbs. of steel.

CEC has an exclusive license to sell and service these furnaces, the Roots pumps, and accessories. For a complete discussion of these proved furnaces, write for Bulletin 4-27.

*The smallest of these furnaces also operate with nonconsumable electrodes



Ingots of 16" diameter can be processed in this Model VA-L 600 sh Heraeus furnace.

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Rochester Division, Rochester 3, N. Y.

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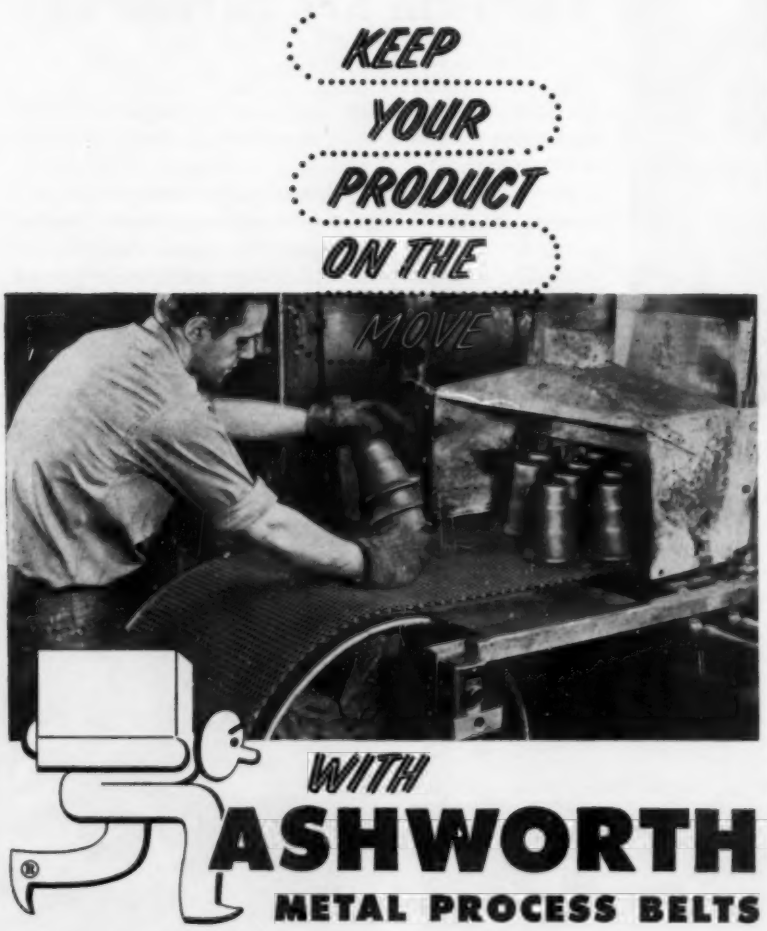
Recrystallization . . .

in very thick sections – all as compared with 7075. This new alloy is obviously less susceptible to recrystallization than 2014 or 2024 shown by Mr. Bennett, but there is insufficient experience at this time to say whether it is quite comparable to 7075 in this respect. The particular section chosen for this comparison indicates that there may be more recrystallization toward the rear of the extruded length than there is in alloy 7075.

At least one of the several possibilities outlined above should avoid trouble with recrystallized areas in aluminum extrusions with very little compromise.

KIRBY F. THORNTON
Sales Development Div.
Aluminum Co. of America



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Temperature Uniformity

CHICAGO, ILL.

Mr. Ipsen's article in your May issue proving that temperature uniformity was better and heating of dense loads faster with forced convection couldn't have been much surprise to *Metal Progress* readers.

However, one statement in the article requires correction. Mr. Ipsen states, "The poorest condition of heating was direct radiation, without use of fan or baffles. As might be expected, recovery time (the interval from insertion of cold charge to the point where furnace heating system goes off full-fire) is normally longer than under convection conditions and becomes more pronounced with increased operating temperature."

Actually, in heating dense loads the exact opposite is true. Let's take a simple example. Place a large sponge in a pail and pour water into it. If the sponge absorbs the water, the water level will rise more slowly than if the sponge fails to absorb the water. Place a load of parts into a furnace. If the charge does not absorb the heat, the temperature obviously rises faster than if, by the use of convection, we drive the gases through the charge thereby increasing its heat absorption. Mr. Ipsen's charts confirm this, since it can be seen that E3 comes to temperature faster than the other E temperatures.

I should also like to know what is a "synchronous speed of 1750 rpm."?

CARY H. STEVENSON
Vice-President
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Sputnik X

Near Miss by a Moon Satellite. Gas cavities in low-alloy steel casting. 9×. The astonished look on the face of the moon speaks for itself. Contributed by H. K. Lloyd, department of metallurgy, University of Nottingham, Nottingham, England

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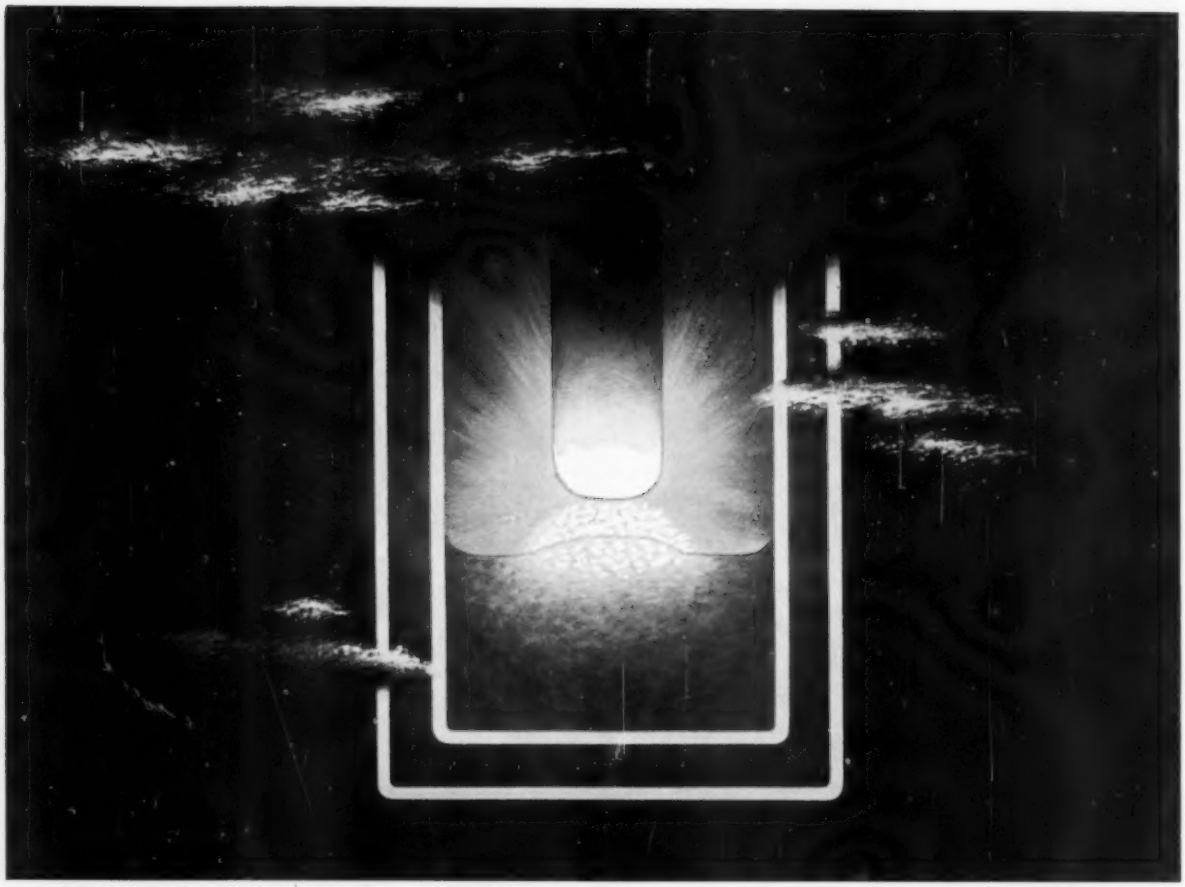

The role of Sylvania consumable electrodes in arc-cast

Metals of the Future

EXCITING and important applications await the development of new high-temperature alloys. Many of these, already in advanced stages of development, are being arc-cast from consumable electrodes.

Working hand in hand with the metal industry, Sylvania has applied its knowledge of powder metallurgy to supply the vital consumable electrode.

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Major advantages of this consumable electrode vacuum process steel are: *Superior cleanliness.* The melting process ends problems of contamination from three basic sources—crucible, air and slag. The water-cooled crucible is made of copper—does not contaminate. There is no air present. And no slag forms. Furthermore, gaseous impurities already in the electrode metal are drawn out by the vacuum during melting.

Better dispersion. Virtually segregation-free steel results because any remaining impurities are better dispersed throughout the steel.

The combination of superior cleanliness and better dispersion results in a more uniform steel of very high fatigue strength and ductility.

This cleaner, sounder steel produced by the consumable electrode vacuum process is ideal for vital aircraft, jet engine and other parts that must have steel that is exceptionally clean and strong.

For further information, please write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

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Personal Mention

H. B. Chambers

H. B. CHAMBERS has been appointed vice-president, metallurgy, of Atlas Steels Ltd., Welland, Ont., Canada. Mr. Chambers will continue to head all metallurgical functions within the organization and retain his position on the company's Management Committee.

After graduation from Lehigh University in 1925 with a bachelor's degree in metallurgical engineering, he worked for Crucible Steel Co. of America, Midland, Pa., and later joined Timken Roller Bearing Co. in Canton, Ohio, where he was a metallurgist for four years. In 1931 he moved to Canada as metallurgical engineer with Atlas Steels, rising to director of metallurgy in 1957.

A naturalized Canadian citizen, Mr. Chambers served the Canadian Government during World War II as a member of various technical committees, and has continued to be active on Government committees.

He is a member of various American and Canadian technical groups, and in 1936 was chairman of the Ontario Chapter.

Eugene S. Machlin, currently on sabbatical leave from his position as associate professor of metallurgy at Columbia University, has been appointed associate research director of the Materials Research Corp., Yonkers, N. Y. For the past few months, Dr. Machlin was acting director of research for the Utica Metals Div., Kelsey-Hayes Co., Utica, N. Y.

William R. Howell, works manager at Crucible Steel Co. of America's Midland, Pa., works since 1947, has been named vice-president, operations, with offices at the company's Pittsburgh headquarters. Mr. Howell has been associated with Crucible for nearly 40 years.

Earl R. Parker, a professor at the University of California, has accepted an appointment as a consultant to the metallurgy department of the scientific laboratory, Ford Motor Co., Dearborn, Mich.

D. J. Mabbutt is now chief chemist and metallurgist for the Parker Pen Co., Ltd., Newhaven, Sussex, England.

M. J. Day has been named to head the new technology department of Crucible Steel Co. of America, Pittsburgh. The new department combines the activities of all metals research, development and metallurgical activities of the company. Dr. Day, formerly vice-president, technology, will be assisted by **Walter L. Finlay**, director of research in the new department. Formerly manager of the Crucible Midland Research Laboratory, Dr. Finlay will be responsible for steel, titanium and special alloys research.

Donald J. McPherson, manager of metals research at Armour Research Foundation of Illinois Institute of Technology, Chicago, received one of five "Distinguished Alumnus" awards of Ohio State University College of Engineering at the Fifth Annual Conference for Engineers and Architects.

Clarence E. Peck, metallurgical process consultant, Westinghouse Electric Corp., Pittsburgh, has been awarded the Trinks Award for his development of controlled gas atmosphere systems and equipment for industrial furnaces. Mr. Peck began his metallurgical career as an assistant to Prof. Willibald Trinks for whom the award is named. He was recently re-assigned to the Westinghouse East Pittsburgh Works after 11 years at the company's Meadville, Pa., plant.

John H. Abbott has been appointed vice-president, sales, for the new Stainless and Strip Div. of Jones & Laughlin Steel Corp., Pittsburgh. The new division was formed by a merger of J&L's Stainless Steel Div. and Strip Steel Div., formerly the Rotary Electric Steel Co. and Cold Metal Products Co., respectively, which were acquired by J&L in 1957. Mr. Abbott formerly held the same position in the Stainless Steel Div. Other members of the new division are: **H. N. Steinberger**, general sales manager; **R. K. Dykema, Jr.**, assistant Cleveland district sales manager; **T. G. Kuzma**, district sales manager in Detroit; **Jack Collins**, assistant Chicago district sales manager; **W. C. Thompson**, district sales manager for the Cleveland office; and **John E. Cottier, Jr.**, Los Angeles district sales manager.

Everett R. Turner, formerly metallurgical supervisor in the research laboratories of Canadian National Railways, Montreal, has been promoted to chief metallurgist.

John C. Schottmiller, after receiving his doctorate degree in chemistry from Syracuse University, joined the Metals Research Laboratories of Electro Metallurgical Co., Niagara Falls, N. Y.

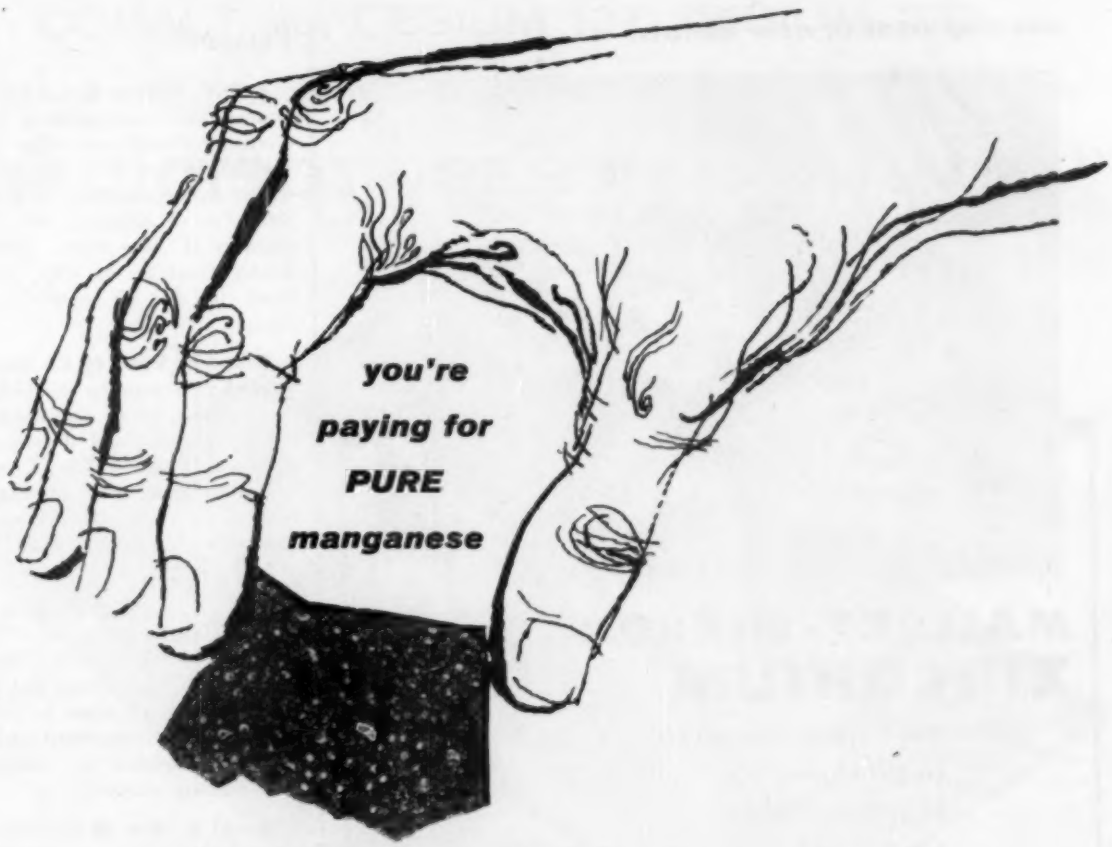
Kenneth Koopman, formerly affiliated with Union Carbide Corp. and Knolls Atomic Power Laboratory, has joined the staff of the Welding Research Council where he will be executive secretary of the High Alloys Committee.

R. P. Baronet has accepted a new position as sales engineer with Peacock Brothers Ltd., Lasalle, Que.

F. H. Mulligan is now affiliated with the U. S. Bronze Powder Works, Inc., Flemington, N. J., where he will handle the marketing of copper alloy powders.

B. D. Bair recently joined the sales department of the H. C. Macaulay Foundry Co., Berkeley, Calif. He was formerly with Engineered Castings Div., American Brake Shoe Co., Rochester, N. Y.

Frederick L. Kundrata is now employed by Ford Motor Co., Dearborn, Mich., as a research engineer at the scientific laboratory.



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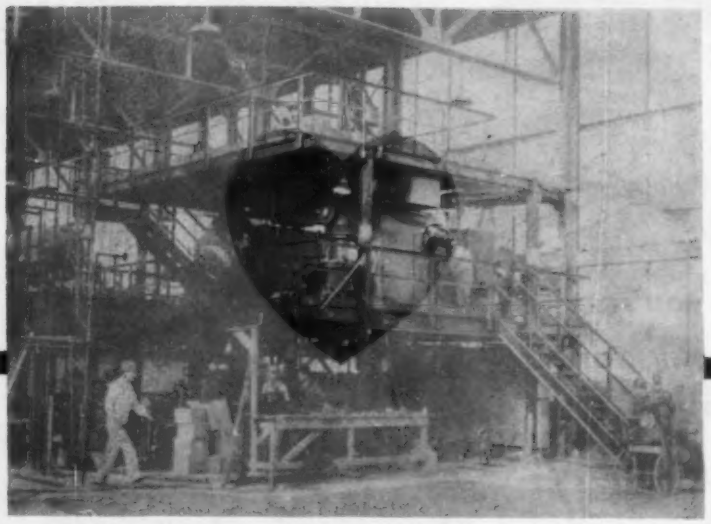

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THE PURPOSE . . . to stimulate the selling of zirconium (and ultimately sodium) by reducing production costs.

Within two and one half years USIC did research, pilot plant work and *began production* . . . a major achievement!

USIC production facilities have now been combined with the fabrication facilities of Mallory-Sharon Titanium Corp., resulting in a new, integrated metals operation, Mallory-Sharon Metals Corp.

Pictured above is a part of the Mallory-Sharon Zirconium plant during the latter stages of its construction at Ashtabula, Ohio.

We here at ZAK are proud that the manufacture of vacuum melting apparatus within the heart of the unit pictured above, was entrusted to us; and we are grateful to National Distillers, P. R. Mallory & Co., and Sharon Steel Corp., equal owners of Mallory-Sharon Metals Corp., for the privilege of sharing in this outstanding engineering feat.

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Personals . . .

John C. Geuther has been appointed sales representative in the Northeast district sales office of the Trent Tube Co., East Troy, Wis., a wholly owned subsidiary of Crucible Steel Co. of America, with headquarters in New York. Prior to joining Trent, he was with Crucible Steel in the Philadelphia sales branch.

Robert H. Shenk has been appointed vice-president and technical director of over-all operations, including research and development, for Zurn Industries, Inc., Erie, Pa. Mr. Shenk returned to Zurn after a number of years with another organization; he originally joined Zurn in 1934.

E. S. Fitzgerald has been promoted to sales engineer at the Cleveland district office of the Timken Roller Bearing Co.'s Steel and Tube Div. He joined Timken in 1948 in the production department and just recently completed the company's sales training program.

Harold K. Myer has been appointed direct field sales engineer for eastern Pennsylvania, southern New Jersey, Delaware and Maryland by Dixon Sintaloy, Inc., Stamford, Conn. Mr. Myer was plant metallurgist in the Stamford plant before taking on his new assignment.

Marshall Sittig, formerly president and managing director of the American Lithium Institute Inc., Princeton, N. J., has joined W. Alec Jordan Associates, New York, as vice-president.

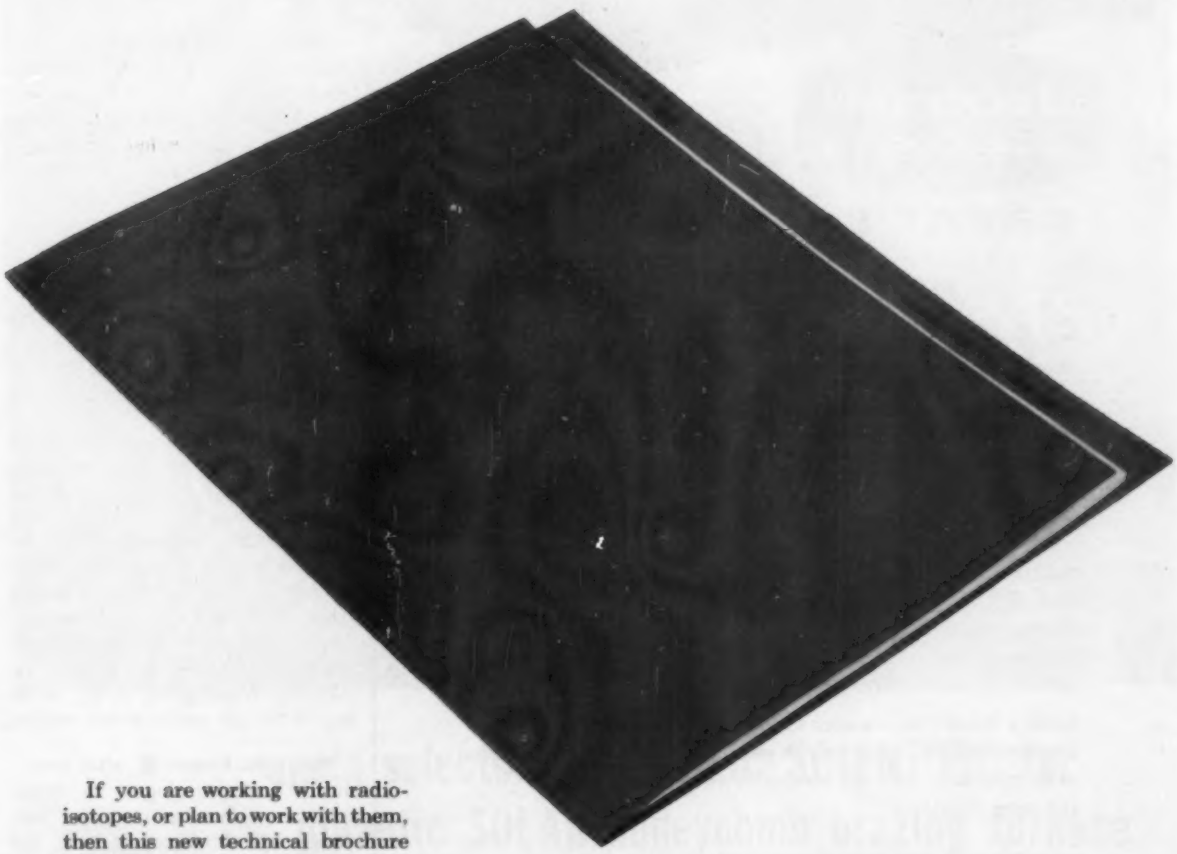
Robert H. Read has been named supervisor of powder metallurgy research at Armour Research Foundation of Illinois Institute of Technology. A member of the metals research department since 1956, Dr. Read had been assistant supervisor of the powder metallurgy section for the past six months.

J. A. Scott, until recently recently research engineer in the bonding branch of the department of metallurgical research, Kaiser Aluminum & Chemical Corp., Spokane, Wash., is now project engineer at Olin Aluminum Technical Center, Olin Mathieson Chemical Corp., New Haven, Conn.

COBALT 60, CESIUM 137, IRIDIUM 192 . . .

the whole story in a nutshell in Ansco's free new

"RADIOISOTOPES IN INDUSTRY"



If you are working with radioisotopes, or plan to work with them, then this new technical brochure is a must for your files.

It gives needed facts and figures on the use of major radioisotopes . . . explains in detail half-lifes, intensity, energy . . . and, describes how each of these characteristics affect exposure time and radiographic quality. It also presents basic exposure factors and compares the quality of radiographs made by exposure to x-rays and gamma rays.

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Ansco

Industrial X-ray

Ansco, Binghamton, New York
Industrial X-ray Dept.

Gentlemen: Please send me a copy of "Radioisotopes In Industry". I am actively engaged in industrial X-ray work.

Name _____

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EBERT SPECTROGRAPH

Switches to direct reading analysis in less than a minute . . . determines up to 20 elements in two minutes . . .

Now you can speed routine analyses photoelectrically, and still solve tough "odd sample" or research problems photographically — all with the same versatile instrument. No "attachments" to mount . . . no tedious realignment. With the turn of a single control you can convert from full-range spectrographic analysis to high speed direct-reading analysis of as many as 20 elements simultaneously.

With the Jarrell-Ash 3.4 Meter Convertible Ebert Spectrograph, you'll enjoy *flexibility* that lets you tackle a greater variety of materials . . . *analytical range* to ferret out unsuspected trace elements . . . *speed* to handle more samples per hour — keep quality control in step with production. And add to these the footstep-saving *convenience* of a single basic instrument with all controls centrally grouped.

Invite a Jarrell-Ash engineer to show you firsthand how the Convertible Ebert Spectrograph will make your analytical efforts more rewarding, your lab operations more productive and more profitable.

- Built-in direct reader photoelectric head fixed in permanent mount — no "attachments" to move or realign.
- Simple, trouble-free optical system — automatically in focus at all times.
- Direct reader dials compute during exposure — results can be read the instant ignition stops.
- Single grating delivers full 20" of stigmatic spectrum.
- Available as conventional spectrograph only, with provision for easily adding direct reader section later if desired.

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JARRELL-ASH CO., 22 Farwell Street, Newtonville 60, Massachusetts

We're interested in learning firsthand, without obligation, how the Jarrell-Ash Convertible Ebert Spectrograph can benefit our specific analytical operation. Please have your applications engineer contact the undersigned.

NAME.....

TITLE..... MP

Personals . . .

Barrett L. Taft has accepted a position as materials engineer for the Florida Research & Development Center of Pratt & Whitney Aircraft. Until recently, he was in the materials control laboratory of Pratt & Whitney, East Hartford, Conn.

Harry F. Ross has left his position as manager of Ipsenlab of Rockford (Ill.), Inc., to accept a job as a metallurgical engineer in the manufacturing engineering group of Sundstrand Aviation Div., Sundstrand Machine Tool Co., Rockford.

Robert A. Davis, previously a development engineer with Kaiser Aluminum Corp., Tacoma, Wash., has taken a new assignment as an associate engineer in the metals group of the transport division of Boeing Airplane Co., Seattle, Wash.

H. A. Moffat is now a West Coast sales manager for Heat Treating Furnaces, Inc., Pasadena, Calif.

George W. Fieser has left his position as project engineer with the nuclear division of American Machine & Foundry Co., Greenwich, Conn., and is now senior engineer for the nuclear division of ACF Industries, Washington, D. C., working on the gas cooler power reactor.

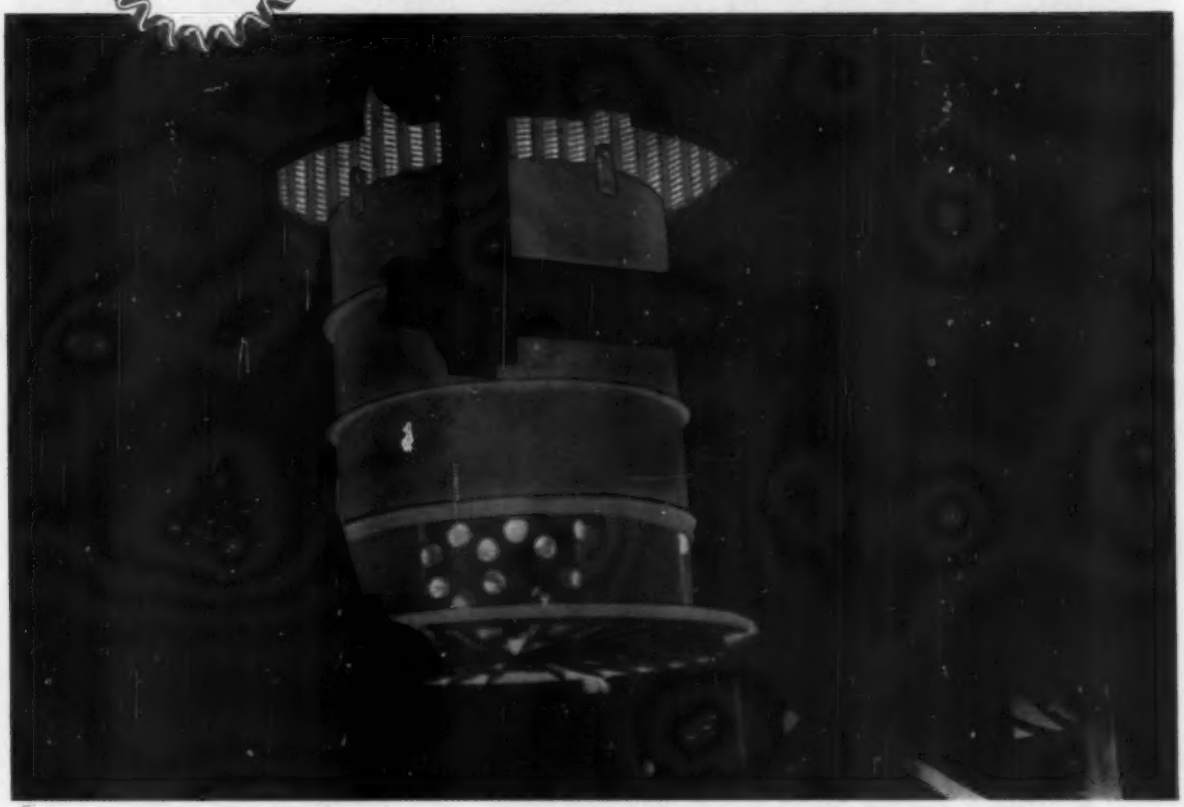
Harry M. Ferrari, after receiving a doctorate degree in metallurgical engineering from the University of Michigan, joined the atomic power department of Westinghouse Electric Corp., Pittsburgh, as a senior research engineer.

Barry Z. Hyatt is now employed as a research metallurgist by the Franklin Institute Laboratories, Philadelphia.

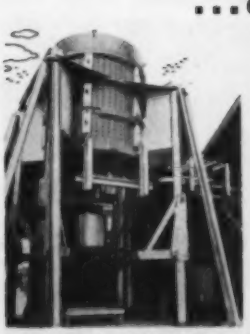
Dale E. Johnson has joined the research staff of General Atomic Div. of General Dynamics Corp., working on research and development of reactor fuel and structural materials.

D. F. Toner has been discharged from the U. S. Air Force, where he worked as assistant professor of metallurgy in the Air Force Institute of Technology, and is now acting as a metallurgist at Oak Ridge National Laboratory.

KANTHAL heating elements



...again selected by PACIFIC SCIENTIFIC for gigantic SOLAR honeycomb brazing furnace



BIGGEST YET! This unique elevator type brazing furnace is the only one of its kind in existence today. Towering 35 feet high, inside dimensions 8 feet by 10 feet, loading capacity of 4000 pounds, power input of 610 KW. Numerous new features enable the furnace to braze, on a production basis, honeycomb panels that will withstand 1600° F. continuously and 2000° F. intermittently.

This unusual furnace built for Solar Aircraft by the Pacific Scientific Company of Los Angeles met rigid design specifications in order to provide extremely close temperature uniformity with fast heating and cooling. Met them so well – in fact – that Solar ordered another similar furnace.

And in both furnaces – KANTHAL A-1 RODS were selected for the heating elements. According to Pacific Scientific . . .

"Kanthal Rods provided the ideal elements for these honeycomb brazing furnaces. A protective oxide film produced by aluminum in the rod alloy at the elevated temperatures permits the wire to give extremely high temperatures for long periods of time without failure when operated in an air atmosphere. Kanthal A-1 elements were used because of their ability to work at these elevated temperatures and to provide excellent service life."

These two Pacific-built Solar furnaces are among the largest KANTHAL installations of rods. Their satisfactory performance is the result of constant KANTHAL research to provide engineers with a broader and better means to solve heating and resistance problems.

Whatever your requirements – KANTHAL can provide an efficient, economical element to meet your needs.

For further specific information and application data – write KANTHAL TODAY!

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Canadian Representative: Ferro Enamels · Ontario, Canada
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A 4-SCREW 1,000,000 LB. HYDRAULIC Universal Testing Machine

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- Selectrange load indicator with 4 ranges.
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Only Tinius Olsen offers a hydraulic four screw high capacity testing machine—unmatched for ease of operation, stability and dependability. Evaluate your high capacity testing requirements in terms of the Olsen Super "L".

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Incidentally, the world's largest testing machine is a 10 million lb. compression unit built by Olsen in 1912 and still used by the Bureau of Standards.

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Personals . . .

Gilbert C. Mott, **Raymond P. Quadt** and **Richard W. Summey** have all been elected to vice-presidential posts at Bridgeport Brass Co., Bridgeport, Conn. Mr. Mott, who has been associated with Bridgeport Brass for more than 20 years, has been promoted from director of engineering to vice-president in charge of engineering. Mr. Quadt, formerly director of research and development, is now vice-president in charge of research and development, while Mr. Summey has been named vice-president in charge of operations.

H. E. Suarez has joined the Hamilton Watch Co., Lancaster, Pa., as senior metallurgist in the metallurgical laboratory. Prior to accepting this post, he was staff metallurgist in the research laboratory of Crucible Steel Co., Pittsburgh.

Gilbert W. Schmitt has accepted a position as plant manager and development engineer at Detroit Kellering Co., Detroit. For the past 17 years, he was employed in the aircraft landing gear division of Bendix Aviation Corp.

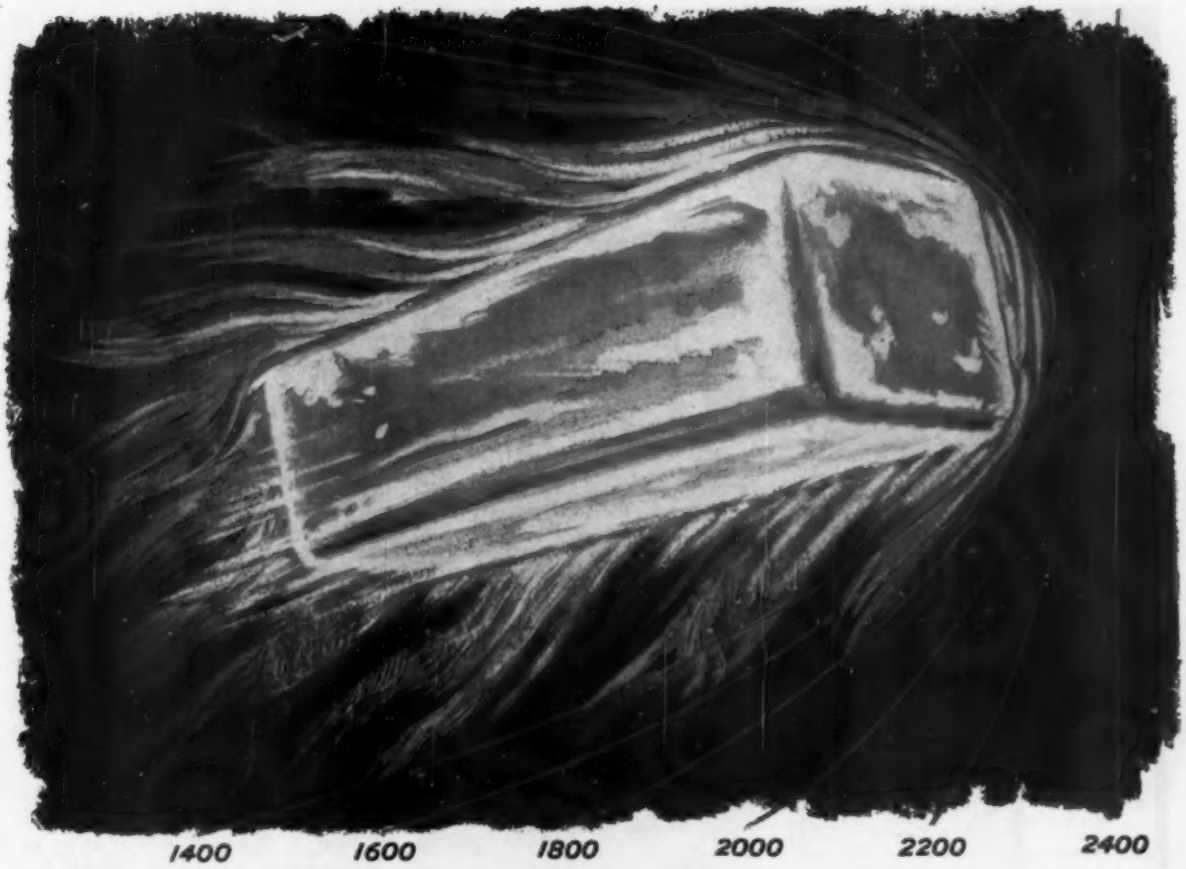
T. G. Odekirk has been transferred from the U.S.S. Tingey, where he was damage control officer, to an instructor's post in the department of naval science at the California Maritime Academy, Vallejo.

P. W. Snyder, a rear admiral in the U.S. Navy, has been detached from duty at the Bureau of Ships in Washington, D. C., to serve as commander of the Puget Sound Naval Shipyard, Bremerton, Wash.

T. W. Bunkhart has retired from the American Can Co. after more than 32 years of service. He was chief designer at its Portland, Ore., machine shop until that shop was closed in 1954.

Pekka Rantala has been promoted to full professor of metallurgical engineering at Purdue University, Lafayette, Ind.

W. A. Firstbrook is now a metallurgical engineer with the sales division of International Nickel Co. of Canada Ltd., Toronto, Ont. Until recently, he was affiliated with Alloy Metal Sales Ltd., Toronto.



Bending the Heat Barrier

Specialized mill equipment is available at HAYNES STELLITE for rolling high-temperature alloys into a variety of shapes and sizes. Bar (above) is being produced on a 24-inch mill.

High strength plus resistance to oxidation, creep, thermal shock, and fatigue—are some of the properties that have helped to push the heat barrier back over the past 15 years. These are the properties found in HAYNES high-temperature alloys. Properties that make these alloys very useful in the 1000 to 2000+ deg. F. range.

Typical uses? The really hot spots in jet aircraft, ramjets, and missiles are some. Furnace components, heat-treating equipment, kiln liners are others. In fact, any part where long service life under severe high-temperature conditions is essential.

There are 12 HAYNES high-temperature alloys—available immediately in convenient forms that can be readily fabricated. For information on properties and prices, write for descriptive literature.

HAYNES
ALLOYS
HAYNES STELLITE COMPANY
Division of Union Carbide Corporation
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UNION CARBIDE

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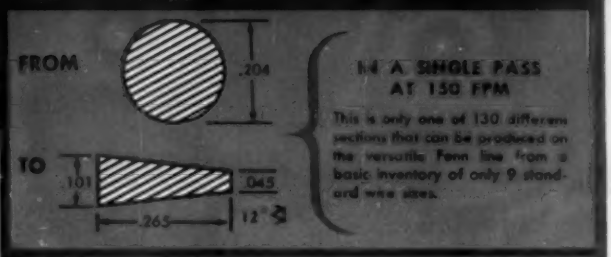
FENN *Precision*

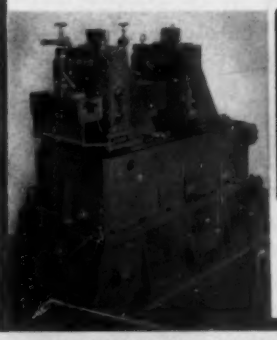
Copper Commutator Bar Line


FROM
.204
TO
.101
.045
.265
12°
IN A SINGLE PASS AT 150 FPM
This is only one of 130 different sections that can be produced on the versatile Fenn line from a basic inventory of only 9 standard wire sizes.

This Fenn line accomplishes several important objectives, in both product and economics. Most important is its flexibility which permits the manufacture of 130 different bar sections from only 9 standard wire gauges . . . substantially reducing basic material inventories . . . and with better quality control. Stock savings alone will amortize its cost in a very reasonable length of time. The basic function of the line is to take coils of round copper wire and form it into a trapezoidal shape of precise tolerances and rewind it at the other end.

The line consists of a Pay-Off Reel, a Model 2U Turks Head mounted to a Model 084 Two-High 8" diameter Rolling Mill, a Model 1244 Wire Shaping Mill with Friction Two Roll Edger, a Model 42 Double Capstan, and a Model 1205 Hydraulic Traversing Take-Up Reel.

The installation of a Fenn line can also have important product and economic considerations in your plant. Write for full information or catalog.



ABOVE—Fenn Model 42 Double Capstan serves as power source for pulling bar stock through wire shaping mill.

LEFT—Fenn Model 1244 Shaping Mill with tandem mounted 4TH Turks Head incorporating shaped rolls.

THE FENN MANUFACTURING COMPANY • 507 FENN ROAD • NEWINGTON, CONN.

Personals . . .

Arnold P. Litman, formerly affiliated with the nuclear division of Black, Sivalls & Bryson, Inc., Tulsa, Okla., is currently working as a metallurgist at the Oak Ridge National Laboratory (Tenn.).

R. W. Flournoy has accepted a post as chief chemical engineer in the engineering services department, Reynolds Metals Co., Richmond, Va.

Prof. William D. Robertson has been appointed chairman of the department of metallurgy at Yale University, succeeding **Prof. Arthur Phillips** who is on leave of absence prior to his retirement in June 1959.

Oscar O. Miller has been elected president of the Technical Societies Council of New Jersey, Inc. Dr. Miller is supervisor of the steel section of the International Nickel Co. Research Laboratory in Bayonne, N. J.

A. L. Feild, Jr., formerly research metallurgist with E. I. du Pont de Nemours & Co. at its experimental station in Wilmington, Del., recently joined the Universal-Cyclops Steel Corp., Bridgeville, Pa., as a research associate. In this capacity, he will be concerned with research and development on refractory metals and their alloys.

Norberto Voloshin has been named chief engineer at Hirt Combustion Engineers, Montebello, Calif. Before joining the organization, he was design engineer in the Industrial Heating Div. of Westinghouse Electric Co., Meadville, Pa.

Ralph L. Wilson, director of metallurgy, Timken Roller Bearing Co., Canton, Ohio, was recently elected to a six-year term as alumnus trustee of Lehigh University.

Heinz V. Menking has been appointed general director of the product development department for Reynolds Metals Co., Richmond, Va. He was formerly director of the transportation section for the product department.

Marion P. McConnell is now a process engineer working on fine wire in nickel alloys for the Driver-Harris Co., Harrison, N. J.

BRISTOL'S

Instrumentation News

• *News of instrumentation and automatic control in industrial heating and metallurgy* •

Instruments help turn out casting cores at 7 tons/hour

Engine blocks for Ford and Mercury automobiles are cast with strictest attention to accuracy and structural quality at the Cleveland foundry of the Ford Motor Company, Brookpark, Ohio, just outside Cleveland.

Yet these rigorous requirements must not impede the smooth flow of the production line. That's one reason Ford installed this battery of Bristol Dynamaster* instruments.

Another: In the early days, core baking used to be an all-night process. Cores were of fine quality, but the output was too low for present-day production lines. The new core baking method turns out top quality cores at the rate of 7 tons an hour. Bristol instruments automatically hold the baking temperature to 450° ± 5°F. And, in emergencies, allow faster processing by raising the temperatures and increasing conveyor speed.

First oxygen steel plant uses Bristol controls

Bristol round chart Dynamaster* Instruments (top) and Bristol Metagraphic miniatures (center row) play a big part in controlling oxygen steel-making at Dominion Foundries & Steel, Ltd.

When Dominion Foundries & Steel, Ltd. (Dofasco), at Hamilton, Ontario, first introduced this method of steel-making to the North American Continent, they chose Bristol instruments and controls (above) to supervise the most critical steps in the process.

These include oxygen pressure and flow (current rate and total), lance position, lance cooling water temperature, flow, and pressure as well as various other temperatures.

The big advantage of oxygen steel-making is the lower original investment in equipment. Only about 50% of the equipment costs of competitive processes is required and operating costs are no higher, with equal or better product.

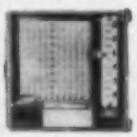
Furnace, oven, dryer— Bristol controls them all

Whatever your industrial heating application, you can find a Bristol instrument or instrument system to provide precision indication, recording or automatic control. The following instruments, in almost innumerable variations, are typical of the truly complete Bristol instrument line.

Bristol's Dynamaster* Potentiometer Pyrometers come in round or strip chart models, provide electronic recording, indication, and electric or pneumatic control, including high-low contact, proportional, time-program and many combinations. The outstanding instrument for maximum precision.

Bristol Millivoltmeter Pyrometers. Both indicating and controlling models available. Controlling models utilize unique Bristol Free-Vane* principle that completely eliminates relay "chatter" or "flutter." High-low contact and proportional models available in a wide variety of combinations.

Bristol Miniature Instruments – Bristol is the only company offering a complete line of instruments in both miniature *and* full-size for all recording, indicating and control applications, both electronic and pneumatic. True plug-in construction. Ideal where panel space must be conserved.



*T. M. REG. U. S. PAT. OFF.

Write for complete data on Bristol instruments for your furnace, oven, dryer or kiln. And remember, Bristol makes a complete line of thermocouples and pyrometric accessories. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn.

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BRISTOL *TRAIL-BLAZERS IN PROCESS AUTOMATION*

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

ROLOCK

FABRICATED HEAT AND CORROSION RESISTANT ALLOYS

Even Rolock's welded-fabrication experts consider these 32-foot Inconel muffle tubes an exacting test of skill. The inset sketch shows how they are made, and the dimensions . . . 32 feet long by only 5½ inches O.A. width and 1 inch inside height . . . leave little room for any inaccuracy. These muffles . . . used for continuous bright annealing of steel strip . . . just *have* to be straight and true when installed, and stay that way in service.

We produce these muffle tubes "by the dozen" for use by the steel strip mills in gas-fired furnaces. Upper and lower sections are assembled separately with diagonal joints welded inside and out. The full length sections are then edge-welded together. Tight specifications call for no weld-splatter on the inside, and each tube is pressure-tested to 25 lbs. p.s.i. before shipment. This is another example of Rolock service to key industries in building and designing many forms of special equipment that modern production processes call for.

If you have a problem in welded-fabrication of high heat and corrosion-resistant alloys, it will pay you to consult Rolock . . . the nationally recognized *specialists* in this field.

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JOB-ENGINEERED for better work
Easier Operation, Lower Cost

9RLB7

Personals . . .

Herbert S. Kalish has accepted a post as section chief, materials, in the metallurgical laboratories of Olin Mathieson Chemical Corp. in New Haven, Conn. Before joining the company's staff, he was engineering manager, metal fabrication and assembly department, Sylvania-Corning Nuclear Corp., Bayside, N. Y.

L. L. Ferrall has been elected executive vice-president of Crucible Steel Co. of America, Pittsburgh. A staff member of the company for nearly 15 years, he was named vice-president, operations, in 1954 and was employed in this capacity until his recent promotion.

W. Kent Kise, Jr., has been appointed metallurgist in the special alloys development group of Carpenter Steel Co., Reading, Pa. Prior to his association with Carpenter, he was chief engineer of the Electro-Plastic Corp., Ft. Lauderdale, Fla., in charge of research and development of high permeability magnetic material components.

Charles M. Bankes has been named manager of sales training for the Carpenter Steel Co., Reading, Pa. Mr. Bankes, who has been a member of the Carpenter organization since 1942, was sales representative in the Providence, R. I., district for the company before his transfer to Reading.

Frederick E. Allison, Jr., is head of the new St. Louis branch office of Latrobe Steel Co., Latrobe, Pa. Mr. Allison joined Latrobe in 1946 as office manager in Detroit, and for the past eight years served as Chicago district manager.

Nicholas Chernik has been promoted to assistant chief metallurgist of the Alloy Tube Div., Carpenter Steel Co., Union, N. J. Before taking on his new assignment, he was a metallurgist for the company.

Jay R. Bonnar is currently serving in the U.S. Air Force as a second lieutenant, assigned to duty as an aircraft maintenance officer. Before entering the service, he worked as a metallurgist for the American Brass Co., Waterbury, Conn., for six months and prior to that was a student at Massachusetts Institute of Technology.

Model U-11

complete only **$1195**

BINOCULAR MODEL only $1379

UNITRON METALLOGRAPH and Universal Camera Microscope, Model U-TI: A completely self-contained instrument of modern design for visual observation, photography, projection and measurement of both opaque and transparent specimens, using bright-field, dark-field or polarized illumination. While compact in size, it duplicates the performance of large, cumbersome instruments. Even laboratories on a limited budget can enjoy the accuracy, speed and efficiency possible only with a complete installation of this type.

- Standard optics include 5 parfocal objective lenses with revolving nosepiece, 4 photographic eyepieces on a revolving turret, 3 visual eyepieces, all coated. Magnification range: 25-2000X.
- High-intensity illuminator with variable transformer built into the microscope base.
- Built-in 3¼" x 4¼" camera. The image is automatically in focus in the camera and transition from observation to photography is instantaneous.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Calibrated polarizing apparatus, transmitted-light accessories for transparent specimens, filters, micrometer eyepieces, film holders, cabinets, dustcovers, etc. all included.
- Additional accessories, available at extra cost include: Polaroid Land Camera attachment for "60-second" photography; 35mm camera attachment; low power (5-40X) objectives; vacuum heating stage for temperatures to 1100°C.

Model MEC

complete only **$399**

BINOCULAR MODEL only $399

UNITRON INVERTED Metallurgical Microscope, Model MEC: Many of the features of the UNITRON Metallograph U-11, which are connected with visual observation of opaque specimens, are included in this compact unit. Think of the time which can be saved in your laboratory by providing each metallurgist with one of these handy, inexpensive units for use at his desk. Model MEC is also ideal for use together with a polisher or microhardness tester.

- Standard optics include 4 parfocal objective lenses: 5X, 10X, 40X, 100X oil immersion on revolving nosepiece; 3 eyepieces: P5X, Micrometer 10X, Ke15X, all coated. Magnification range 25-1500X.
- Vertical illuminator with iris diaphragm. Transformer housed in microscope base. A microswitch on the base provides an extra high intensity for photography.
- Binocular model has provision for attaching 35mm camera to microscope base. A 35mm camera attachment is available to attach to the eyepiece tube of the monocular model.
- Calibrated square mechanical stage with calibrated rotatable stage plate.
- Calibrated polarizing apparatus, 5 filters, dustcover, cabinet, etc. all included.
- Additional accessories available at extra cost include: 35mm camera attachment; K20X eyepiece for 2000X; transmitted-light accessories for transparent specimens; vacuum heating stage.

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Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Vacuum Degassing

Digest of "Vacuum Casting of Steel", by John N. Hornak and M. A. Orehoski, U.S. Steel Corp., Monroeville, Pa. Presented before Technical Conference on Quality Requirements of Super-Duty Steels, A.I.M.E., Pittsburgh, May 5-6, 1958.

THE SUCCESS of vacuum degassing in Europe has led to the installation of similar equipment in this country. Large ingots, suitable for turbine rotor fabrication and containing less than 1.5 ppm. hydrogen, are being cast regularly. The story of the design, construction and operation of this equiment makes interesting reading.

To begin with, it was decided that a final hydrogen content of less than 1.5 ppm. in the casting had to be planned for to avoid any possibility of subsequent flaking or embrittlement. Vacuum pumps would not only have to handle the large volume of gas emerging from the air-melted steel but also compensate for any leaks which might occur. Many assumptions had to be made since no previous experience was available. Calculations based on these estimations indicated that the pumps would have to maintain a pressure of 0.65 mm. of mercury or less.

Vacuum Pumps – Steam-ejector units were selected because:

1. Substantial quantities of steam were available at the site to be used for the vacuum-casting equipment.

2. Steam ejectors cost less and are compact; the system would fit into a vacant area in the existing building.

3. The steam ejectors have no moving parts and do not require oil changes.

Vacuum Tank – This was designed on the principles of a bell jar large enough to handle a 110-in. mold (for a 235-ton ingot) and hot top. Refractory materials and water cooling were avoided to reduce sources of moisture. It consists of two sections – a tank base 28 in. deep, and a tank top 28 ft. high. The inside diameter is about 15 ft. The tank top rests on a grooved flange of the base, with the joint between these two sections being sealed by a neoprene "O" ring.

To prevent overheating of the tank top by the radiation from the stream and rising metal, a shield is provided on the underface of the tank top. This, combined with the air cooling outside the top, maintains a sufficiently low temperature. The major load (ladle and metal) is placed on external supporting mem-

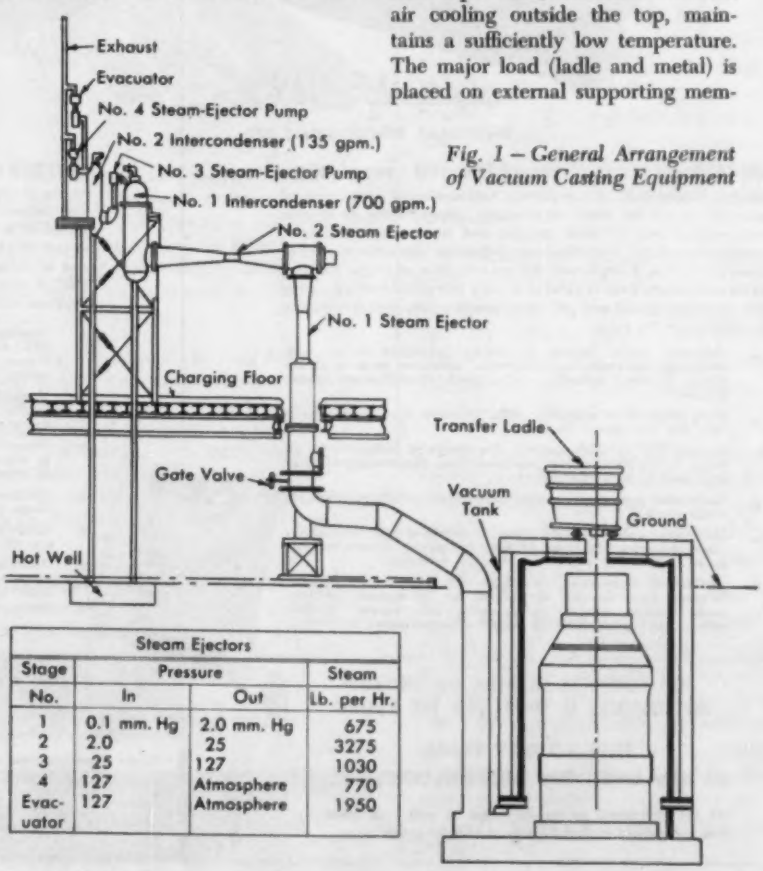
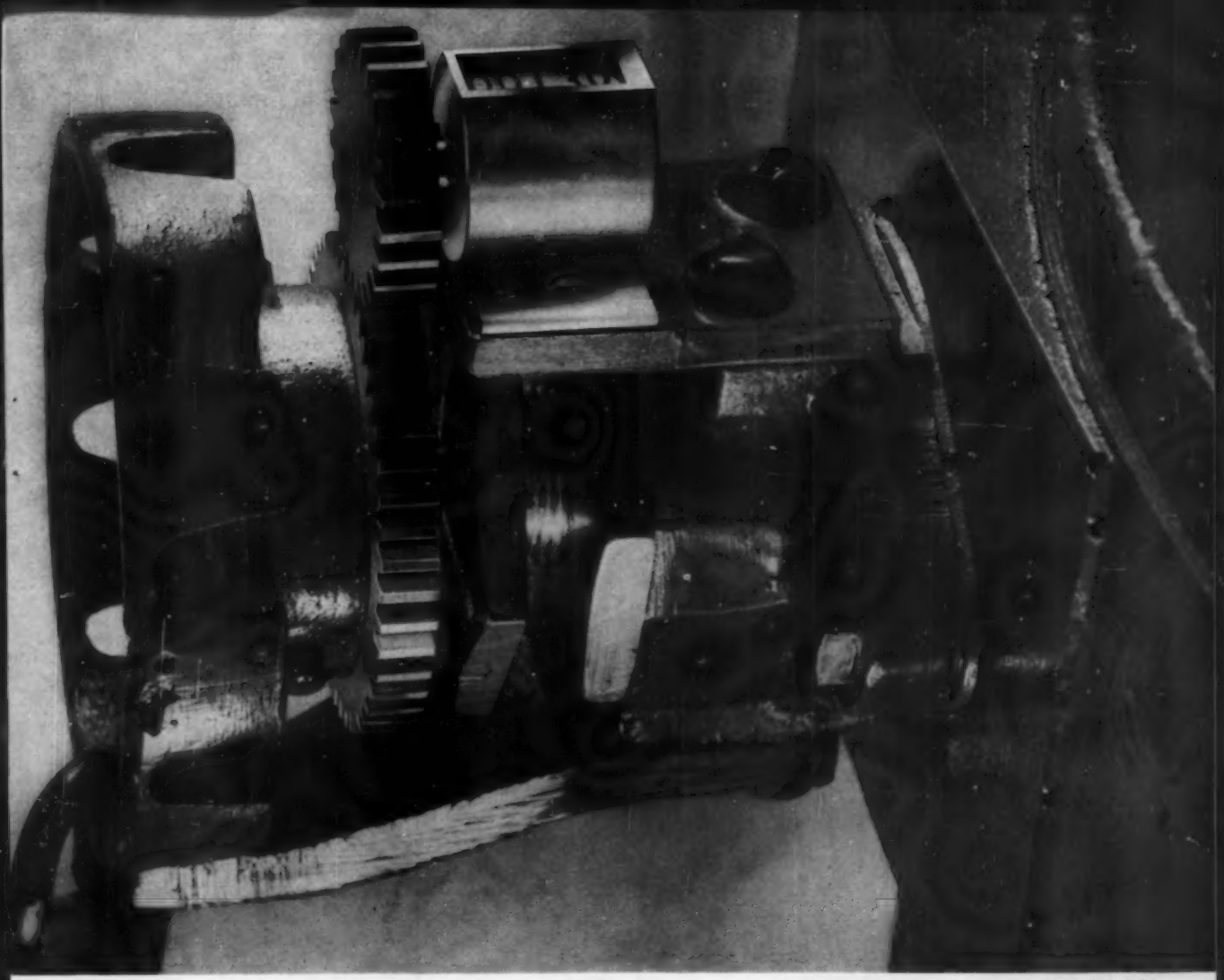


Fig. 1 – General Arrangement of Vacuum Casting Equipment

Steam Ejectors			
Stage No.	Pressure In	Pressure Out	Steam Lb. per Hr.
1	0.1 mm. Hg	2.0 mm. Hg	675
2	2.0	25	3275
3	25	127	1030
4	127	Atmosphere	770
Evacuator	127	Atmosphere	1950



Air-gas Ratio Valve

For precise control of furnace atmospheres . . .

Come to Kemp

Twin installation of Model 6-MR Atmos Gas Generators deliver up to 6,000 cfh at Thomas Strip division of Pittsburgh Steel. Increased equipment capacity, reduced labor costs, and closer control make Kemp units money savers in every installation.

For heat treating and annealing metals in inert atmospheres, you can rely on Kemp Atmos or Nitrogen Generators as a dependable source of inert gasses. Kemp generators are built around the patented Kemp Industrial Carburetor, which guarantees a steady supply of exact analysis inerts, regardless of demands on the line. With Kemp units supplying your furnaces, you get greater control . . . a better product at lower cost.

The Kemp Atmos Generator, a rich exothermic gas producer, is suitable for most furnace applications; while for more critical uses the Kemp Nitrogen Producer is recommended. Both are noted for durability and dependability. Rugged Kemp design gives optimum performance for years, with only minimum maintenance and care.

Kemp generators may be engineered as an integral part of new furnace construction, adapted to existing units, or furnished as a separate setup.

Your Kemp Representative, listed in the Chemical Engineering Catalog, will give you complete details. Or write direct for Bulletins I-100 and I-101. The C. M. Kemp Mfg. Co., 405 E. Oliver St., Baltimore 2, Md.

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Vacuum Degassing . . .

bers; therefore, the tank proper, which supports only its own weight and atmospheric pressure, is made of relatively light plate.

Figure 1 is a schematic drawing showing the general arrangement of the vacuum-casting equipment. The exhaust line connecting the vacuum tank base to the first stage of the steam-ejector system is 36 in. in diameter. A control valve, needed to check the pumping system and the tank seals, is located in the exhaust line upstream of the first steam ejector.

Operation of Equipment

Both start-up and shutdown follow a prescribed sequence. No. 4 steam ejector and the evacuator are started first. When the desired pressures are obtained, cooling water for the No. 2 intercondenser is turned on and the No. 3 steam ejector actuated. After the desired pressure levels are again reached, the water for No. 1 intercondenser and the steam for No. 2 and No. 1 steam ejectors are turned on in that order. The evacuator is operated for a limited time only, since its main purpose is to reduce the total time required to obtain a vacuum-tank pressure of 0.1 mm. of mercury. When the desired pressure level is obtained, the evacuator can be shut off, and the pumping system operated with four ejectors only.

To check the inleakage and pump performance, the gate valve in the exhaust line is closed after the pressure in the tank has been reduced to about 0.1 mm. mercury and the pressure rise noted for a 5-min. period. Experience has shown that inleakage rates as high as 500 microns per min. are acceptable. Leaks that cause inleakage rates greater that this should be located and eliminated because they overload the pumps, cause high blank-off and operating pressure, and introduce excessive quantities of air.

After these tests, the unit is ready for operation. The tapping ladle is set atop the transfer ladle, and the nozzle opened. When the transfer ladle is about three-quarters full, the nozzle is opened, and the metal pours into the mold. A special refractory collar controls spraying; this results in an ingot surface com-

parable to, or better than, that of a similar air-cast ingot.

Casting pressures vary throughout the pour. In one instance, the initial tank pressure was less than 100 microns. It suddenly increased to 500 microns with the initial splash of steel, and gradually decreased to less than 400 microns until the hot-top junction was reached. While the hot top was being filled, the pressure decreased because of a lower pouring rate. The pressure would have risen if the hot top had not been properly dried. Experience with the equipment revealed that a

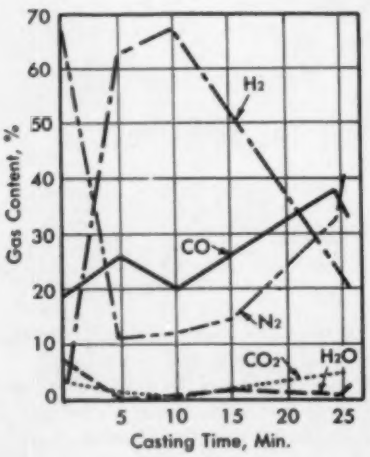


Fig. 2 – Variation in Gas Content With Casting Time

pressure of around 0.5 mm. mercury or less was needed to reduce hydrogen to less than 1.5 ppm.

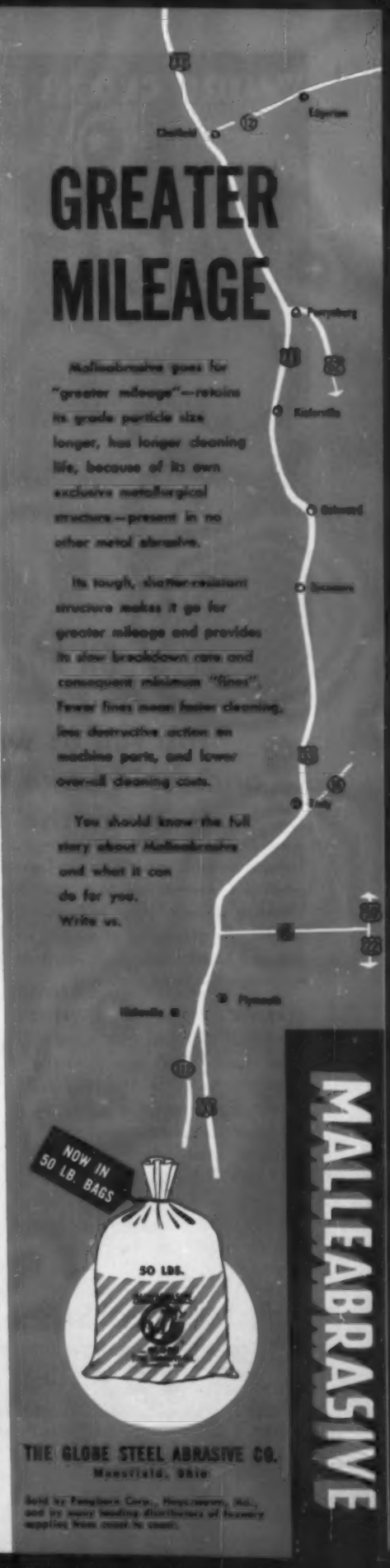
In some instances gas samples were collected periodically during the pour. Figure 2, a plot of data for a single ingot, shows that gas composition varied considerably throughout the operation. Another worry was the possibility of flammable gas mixtures inside the tank. To avoid flammable gas regions when breaking vacuum, hydrogen should not exceed 4%, and carbon monoxide 14%. To meet these conditions, the tank must be purged with an inert gas, such as nitrogen, before the gas mixture is exposed to air. Limited studies by the U.S. Bureau of Mines indicated that flame propagation could be developed at an absolute pressure of 6.5 mm. of mercury and at a partial pressure of hydrogen as low as 2 mm. of mercury.

The table shows the hydrogen, oxygen, and nitrogen concentrations in typical ingots before and after vacuum casting. Hydrogen was removed effectively, oxygen passably, and nitrogen hardly at all. The success in hydrogen removal can be attributed to the gas's high diffusivity and vapor pressure. Since aluminum and other strong deoxidizers (which form stable oxides) were not used in making the heats, these steels could be further deoxidized by the reaction of carbon and oxygen when exposed to reduced pressures. The inability to remove nitrogen may be associated with the composition. Some elements increase the solubility of nitrogen or form stable compounds so that very low casting pressures, below the decomposition pressure of the nitrides, are required to remove nitrogen.

Ductility is considerably improved by vacuum casting; this is especially true of unaged material. The removal of hydrogen also reduces flaking. In the flake-sensitivity test, a section of the top discard is forged to a 16-in. square and hot sheared into several 28-in. pieces. The pieces are then subjected to various cooling rates which include water quenching, air cooling, and slag cooling. After the pieces have remained at room temperature for a suitable time to allow for the incubation of internal defects, they are cut, deep etched, and examined for flakes. A typical test piece water

Average Gas Content of Heats Before and After Vacuum Casting, Ppm.

Ingot No.	Hydrogen		Oxygen		Nitrogen	
	Before	After	Before	After	Before	After
1	3.3	1.0	40	25	30	30
2	5.1	0.8	20	15	60	55
3	4.7	0.8	25	15	70	65
4	4.9	0.8	20	10	80	80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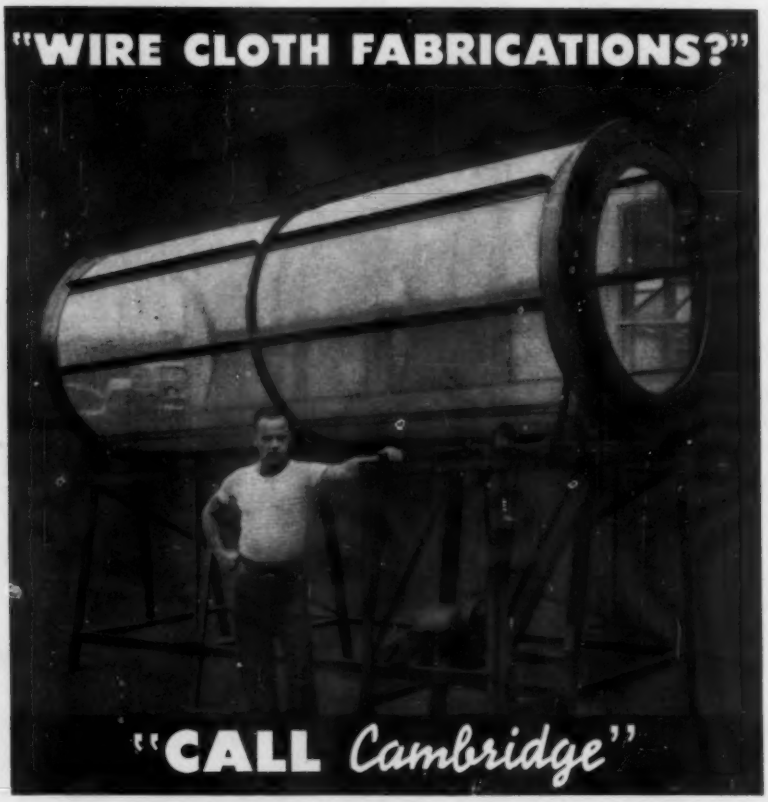

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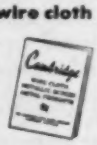

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Vacuum Degassing . . .

quenched from 1475° F. showed no flaking. (A similar test of an air-cast steel would be severely flaked.)

In summary, vacuum casting successfully reduces the hydrogen concentration to a level at which the steel is insensitive to flaking. Also, the tensile ductility for aged and unaged specimens is approximately the same. The pressures at which the process is conducted, however, need special attention for both equipment preparation and actual casting. With adequate precaution, little or no difficulty should be experienced. C.R.W.

Vacuum Degassing at Bethlehem

Digest of "Vacuum Pouring of Ingots for Heavy Forgings", by J. H. Stoll, Bethlehem Steel Co. Paper presented before American Iron and Steel Institute, New York, May 21, 1958.

WITH FORGINGS getting continually larger and more heavily alloyed, the danger of flaking due to hydrogen has constantly increased. Recognizing that the elimination of hydrogen during melting was virtually impossible, Bethlehem decided to investigate the vacuum degassing process. Early in 1956 a unit capable of handling a 7-ton ingot was built and operated in order to work out the mechanics of the procedure and to evaluate the benefits of vacuum pouring. The lessons learned made it possible to place the two 250-ton units built in 1957 in immediate production.

The diagram on p. 148 is one of the large units. It is equipped with a high-speed movie camera to record the effect of practice changes and two television cameras to observe the stream. A four-stage steam-jet ejector system evacuates the tank to a 300 to 400-micron pressure after the tank and mold have been carefully cleaned and dried. Air-melted steel pours into the pony ladle; when this is full enough, its stopper is opened and the mold is filled rapidly. The flow is slowed while the hot top is filled; otherwise the surging steel will slop over the edge. Solidification takes place in the tank – this

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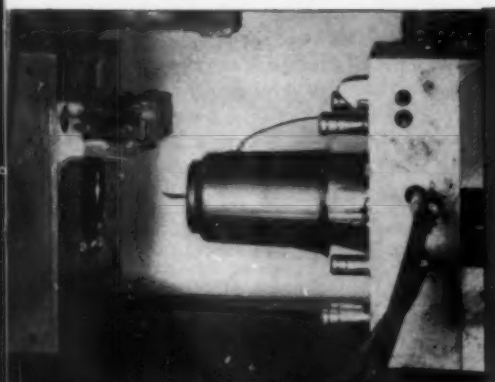

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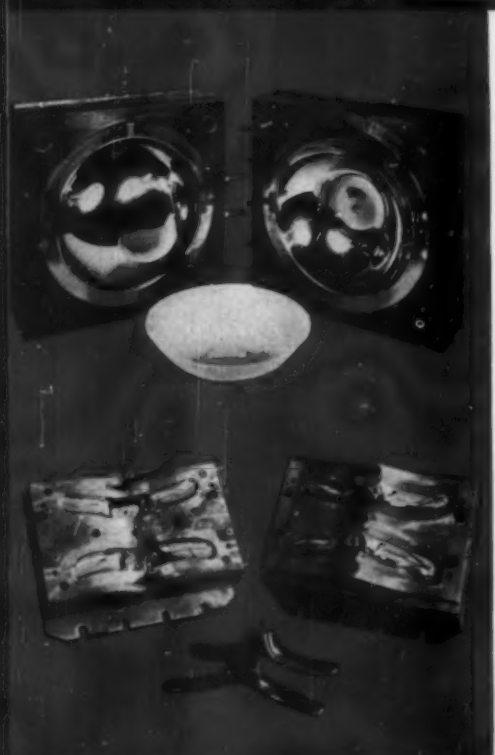

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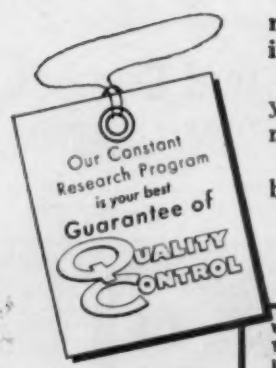

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Vacuum Degassing . . .

lasts 40 hr. for a 92-in. 280,000-lb. ingot. The tank exterior is water cooled for this period.

About 60% of the hydrogen in the air-melted steel is removed by degassing; this reduces it from an average of 3.2 to 1.2 ppm. in the hot top. Furthermore, the hydrogen content is about 0.5 ppm. from surface to center of vacuum-poured ingots, while it rises from 0.7 at the surface to 3.2 ppm. in the center of conventionally cast ingots. Cleanliness and ductility are both improved, and flaking virtually eliminated.

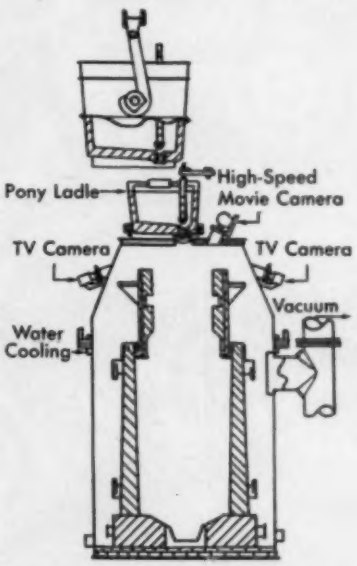

Fig. 1 – Diagram of 250-Ton Vacuum Degassing Unit

Cost is higher for vacuum-poured steel not only because of the initial equipment investment but also because of operational expenses. More men are needed, molds must be prepared more carefully, and refractories are more expensive. Hazards attendant to production of large ingots are also increased by vacuum pouring, since damages occasioned by such items as running stoppers and steel leaks are more serious.

Despite the extra cost and the drawbacks, it appears that large forging ingots will be vacuum poured more and more in the future.

C.R.W.

EDITOR'S NOTE: Erie Forge & Steel Co., Erie, Pa., also has vacuum degassing equipment.

MOLY NEWS
CLIMAX MOLYBDENUM • DIVISION OF AMERICAN METAL CLIMAX, INC.

Climax Develops an Extremely Tough, Abrasion-resistant Chrome-Moly White Iron

New Alloy Proves Superior in Erosive Applications

A new martensitic white iron has proved exceptionally tough and resistant to abrasion. It's called Alloy 42. Its excellent combination of properties are related to its structure — which consists of hard chrome-moly carbides favorably distributed in a matrix of martensite plus retained austenite.

Tests indicate Alloy 42 is especially economical for parts subject to erosive wear: sand pumps, flotation impellers, sand classifier wear shoes, pug mill blades, brick mold liners and chute liners.

For example, heat-treated Alloy 42 impellers in a 5" sand pump handling coarsely ground taconite ore have already lasted over 1,000 hours. Previous impellers made of a 4.5% Ni, 1.5% Cr type of martensitic iron lasted only 350 to 400 hours.

Because of its toughness, Alloy 42 can also be used where moderate impacts would cause low alloy types of white iron to break or spall. And it may prove more economical than the soft rubber parts or linings now used in various abrasive applications. Its resistance to tearing by tramp coarse materials and chemical attacks by oils and other organic compounds is an obvious advantage.

The recommended composition range is: Carbon 3.00-3.50%; Silicon 0.30-0.60; Manganese 0.60-0.90; Chromium 15.0-18.0; Molybdenum 2.75-3.25.

A Climax bulletin on Alloy 42 discusses melting and casting, molds and shrinkage, heat treatment, structure, physical properties, machinability, welding and cutting. *For a free copy, circle #1 on the coupon.*

Heat Treating Improves the Wear Resistance of Gray Iron

Heat treating can improve many of the properties of gray iron, particularly resistance to wear. Wear resistance in quenched-and-tempered gray iron is many times greater than that of pearlitic irons. With cams and similar parts, hot quenching provides better wear resistance than quenching and hardening to the same hardness. Surface hardening is frequently selected for gray iron because it locally improves wear resistance with minimum distortion.

Why Moly Iron Bulletin #6 contains valuable information on surface hardening, annealing and stress-relieving molybdenum-alloyed irons. This bulletin gives examples of improvements obtained by heat treating gears, cable drums, pump-ring castings, tappets, valve guides and machine tool ways.

Flame hardening the teeth on a sprocket improves wear resistance with minimum distortion.

*For a free copy of **"Why Moly Iron Bulletin #6,"** circle #2 on the coupon.*

Tempering Low-Alloy Creep-Resistant Steels

A recent British paper discusses the roles of chromium, molybdenum and vanadium in low-alloy steels with high creep strength. The relation between creep properties, microstructure changes and carbide composition is given special attention.

*For a copy of **"The Tempering of Low-alloy Creep-resistant Steels Containing Chromium, Molybdenum and Vanadium"** by E. Smith and J. Nutting, circle #6.*

Moly Helps High Alloys Fight Corrosive Attacks

Highly alloyed materials are playing a greater part in combating corrosion. A current paper on these alloys considers the molybdenum-bearing alloys at length and also discusses cobalt-base alloys and silicon-bearing alloys.

*For copies of this paper, **"High Alloys to Combat Corrosion"** by E. D. Weisert, circle #7.*

Thermenol Shows Excellent Resistance to Heat, Corrosion

Thermenol, an iron-aluminum-molybdenum magnetic alloy, compares favorably with other high-temperature materials, and in some cases promises even better service. For unlike many alloys, it doesn't lose tensile strength rapidly up to 1200 F. It also has excellent resistance to oxidizing and sulfur-bearing atmospheres at high temperatures.

*For a copy of **"Iron-aluminum Magnetic Alloy Has Excellent Heat Resistance,"** circle #8.*

Moly in Nickel-base Casting Alloys Improves High Temperature Service

Molybdenum is helping at least two nickel-base alloys to work more effectively in high temperature applications. One of the alloys, with 5% Mo, combines good castability with very good creep strength at temperatures up to 1800 F (much better than that of moly-free alloys). The second, with 10% Mo, shows high resistance to thermal shock.

*For free copies of **"Some Properties of Nickel-base Casting Alloys for High-temperature Service"** by D. R. Wood and J. F. Gregg, circle #3.*

Cast Steels Studied at Low Temperatures

The British Steel Castings Research Association has completed new studies on the effect of melting practice, composition and treatment of steel castings. Five of the seven alloy steels investigated contained molybdenum. The benefits of using molybdenum in low alloy steel castings for low temperature service are clearly shown in comparisons of 1.5% Mn and 1.5% Mn-Mo.

*For reprints of **"The Low-temperature Impact Properties of Cast Steel"** by W. J. Jackson and G. M. Michie, circle #4.*

New Data Available on Low Carbon Bainitic Steels

Studies have been made on new steels based on boron-0.5% Mo. Tensile strengths up to 180,000 psi can now be obtained within the bainitic range with a wide range of cooling rates. Thus these low-carbon bainitic steels offer a good combination of mechanical properties as-rolled or as-air-cooled. These properties can be obtained in large sections because hardenability is high. Good welding properties and tempering characteristics make the steels especially suitable as high-strength weldable steels, forgings, die blocks, etc.

*For copies of **"Low-carbon Bainitic Steels"** by K. J. Irvine and F. B. Pickering, circle #5.*

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Abrasion Resistance of Weld Deposits

Digest of "The Effect of Carbon on the Resistance of Hard Facing Deposits to Abrasive Wear", by E. I. Leynachuk, *Automaticheskaya Svarka*, No. 3, 1957, p. 58-64.

CARBON, as a cheap and available ingredient of hard-facing alloys, is of great practical interest. This paper is an inquiry into the effect of carbon on abrasion resistance apart from its effect on hardness.

All deposits were made by submerged-arc welding with a cored electrode. Varying amounts of carbon were added to the deposit by adjusting the carbon content of the core. The welding flux contained no manganese.

The first series of experiments consisted of depositing three beads of each electrode on a mild steel plate ¾ in. thick at 280 to 320 amp., 28 to 32 v., 12 in. per min. Each bead overlapped the next by half its width. There was no preheat and the deposits cooled in air. Twelve deposits were tested ranging in carbon content from 0.17 to 2.54%. The manganese and silicon varied from 0.39 to 0.54 and 0.06 to 0.15%, respectively. The Brinell hardness rose from 110 at the lowest carbon level to 421 at the highest carbon level.

The abrasion resistance of these deposits was tested on a machine described by R. D. Haworth (*Iron Age*, Oct. 7, 1948, p. 82-87). The specimen was held at the end of a weighted lever which pressed it against a transversely notched rubber wheel 10 in. in diameter. The transverse cuts held granite powder from a water suspension into which the wheel dipped. The wheel rotated at 240 rpm. The granite powder particles were 0.016 to 0.08 in. in diameter. The pressure on the specimen was 42 lb. Results were expressed as weight loss in grams in 10 min., using five specimens.

As the carbon content of the deposit increased from 0.17 to 2.10%, the weight loss fell from 2.81 to 0.74 g. Beyond 2.19% there was little further decrease in wear.

A series of specimens was heat treated to the same hardness to assess the effect of carbon alone on abrasion resistance. Water or oil hardening

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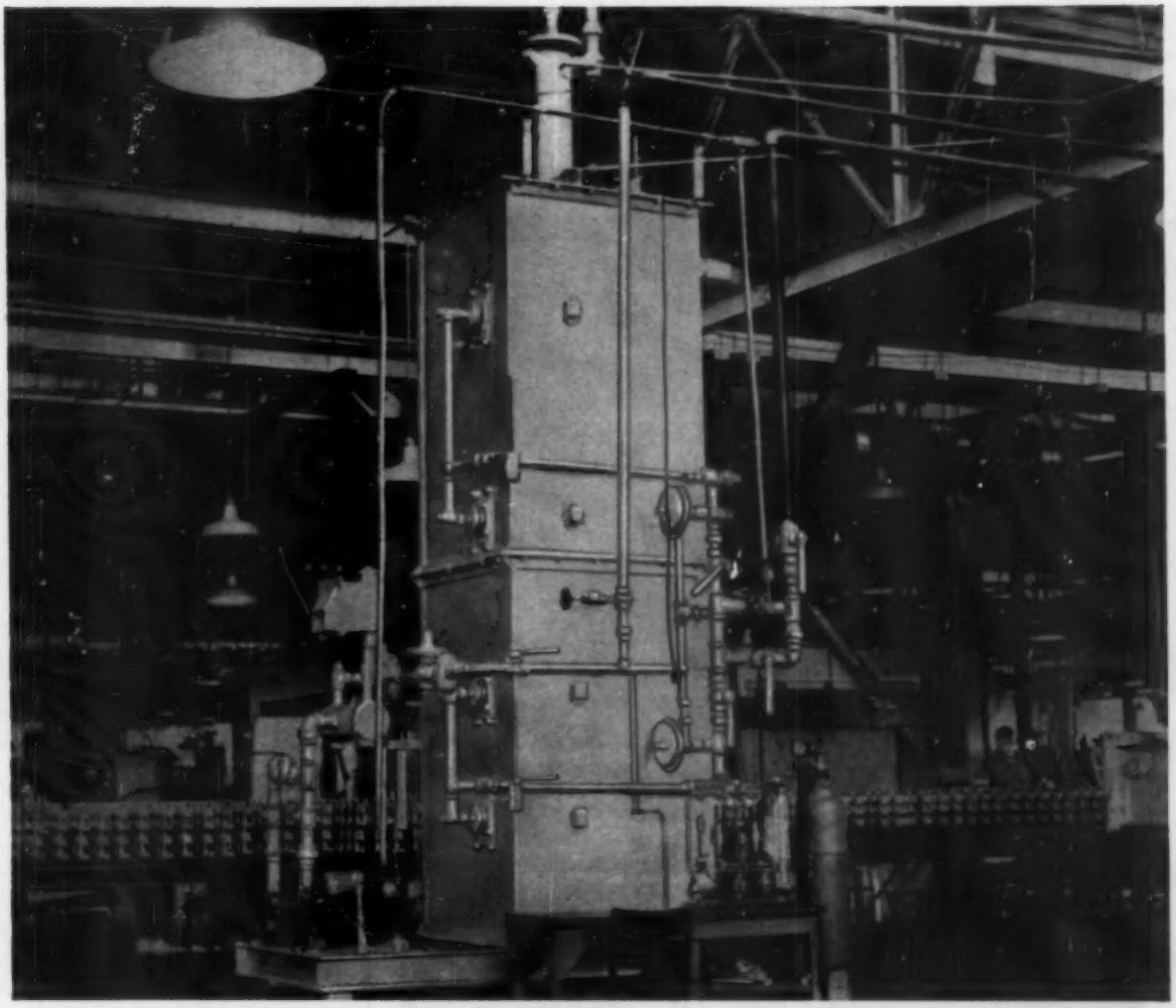

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Abrasion Resistance . . .

produced a series of specimens at Brinell 395 to 421 with carbon from 0.24 to 1.68%. Wear fell from 1.03 g. at 0.29% C to 0.67 g. at 1.68% C. Metallographic examination showed that the 0.29 and 0.42% C deposits were troostosorbitic. The specimens with 0.96% C had some grain-boundary cementite, and more was present in the specimen with 1.86% C. Grain size was 7 to 8. The higher wear resistance of the higher carbon deposits was believed due to the presence of cementite and to the predominance of troostite over sorbite. The wear in the hardened condition was 20 to 45% less than before hardening.

These specimens were then drawn at 1112 to 1256° F. for 1½ hr. and cooled in air. The hardness was Brinell 212 to 302. The wear fell from 1.84 g. at 0.29% C to 1.24 g. at 1.68% C. Drawing increased the wear beyond that observed in the as-welded condition.

The tests show that an increase in carbon content to 2.54% in an unalloyed deposit reduced the wear by a factor of three or four compared with a low-carbon steel. The increase in wear resistance with carbon content of deposits hardened to the same Brinell level was ascribed principally to the presence of increasing amounts of grain-boundary cementite. G. E. CLAUSSEN

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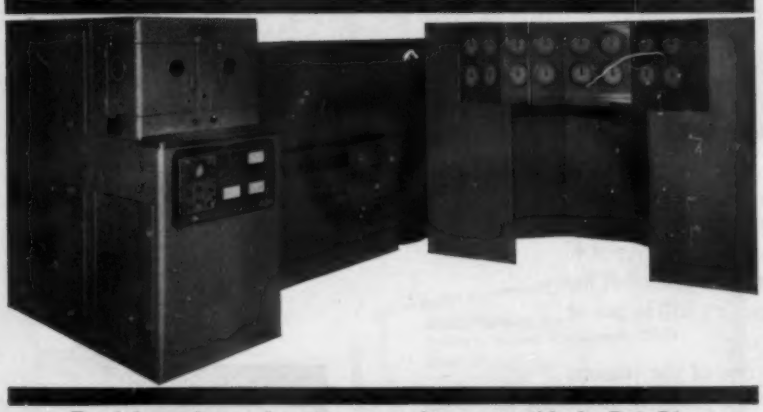

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Pouring of Uniform Ingots

Digest of "Yield Control by Means of Electronic Weighing", by W. A. Black, Republic Steel Corp., Cleveland. Paper presented at the 41st A.I.M.E. Openhearth and Blast Furnace Conference, Cleveland, April 1958.

A METERING SYSTEM now in use at the Youngstown, Ohio, plant of Republic Steel Corp. weighs ingots automatically as they pour from the ladle. Sensitive gages attached to the ladle hook vary in resistance (due to change in length) as steel pours from the stopper; these variations actuate the control mechanism of the hydraulically operated stopper rod through an electronic linking system shutting off the flow when the desired weight is reached.

Many problems were solved in making this scheme operative. For example, strain gages had to work continuously and accurately a short distance above a cauldron of molten steel. The gages have circuitry to compensate for the heat rise, and are also hermetically sealed in a sturdy case for protection from dust and moisture. Experimental work indicated that the input transformers varied in resistance, the variation showing up as a weight loss. This problem was solved by rewinding them with wire of larger diameter.

Electric preset counters link the gages with the stopper rod. They meter the metal as it is dispensed, and activate the solenoid valves to close the nozzle at the proper point.

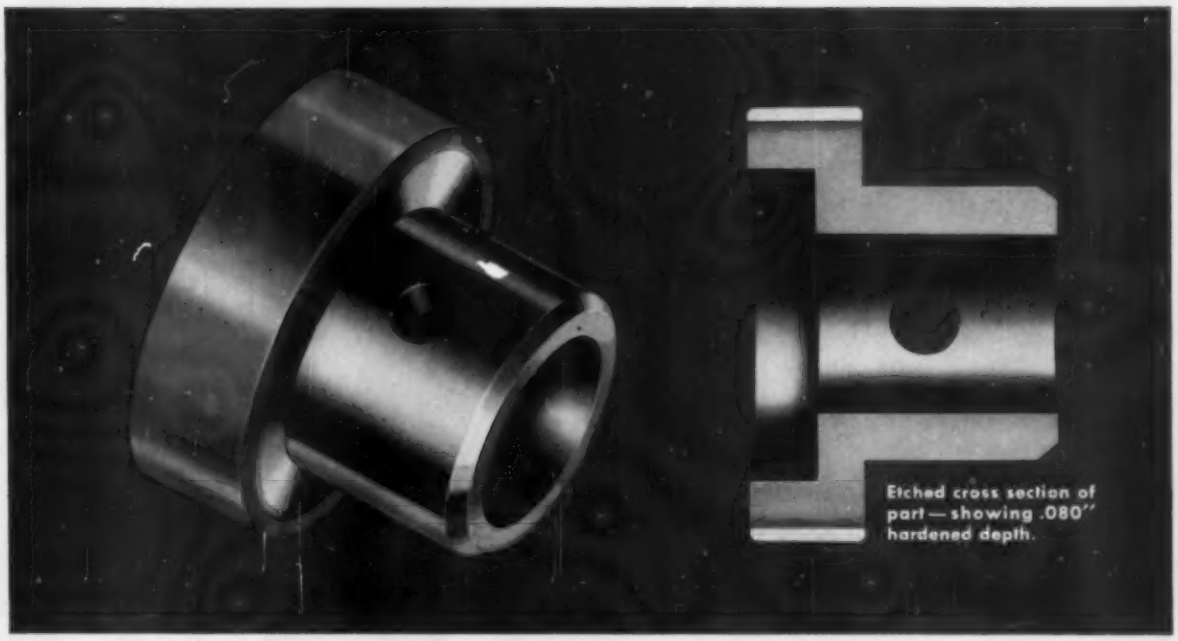
For operation, the three elements of the weighing setup are connected and the ladle centered over the mold. The ladleman opens the nozzle, and

Costs Cut 94%

with

TOCCO* *Induction Heating*

A cost reduction of 94% resulted when heat-treatment of this Corn Harvester part was changed from carburizing to TOCCO-hardening. Look at the unit cost breakdown:



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External Grind	0.0166	eliminated	
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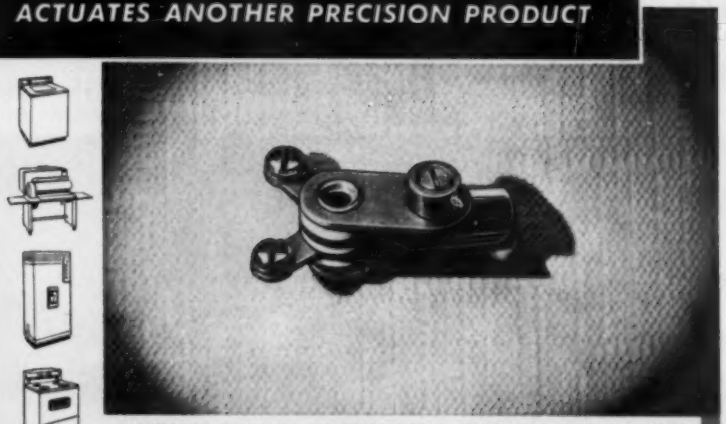

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Uniform Ingots . . .

steel pours into the mold. When it is nearly full, a horn blows warning the operator to reduce the flow. The stopper closes automatically when the correct weight is reached.

The aim is control within 1% of the ingot weight; at present, weighing of the ingots immediately after pouring indicates that 69% are within this figure under optimum conditions. Further experience with the equipment should raise the accuracy appreciably.

C.R.W.

Adhesive Bonding of Metals

Digest of "Adhesive for Metals", by A. E. Williams, *Iron and Steel*, Vol. 31, January 1958, p. 11-14.

THE BONDING of metals by means of a film of adhesive has been developed to a stage where it can be considered alongside time-honored methods of joining such as soldering, brazing, welding and riveting. Originally developed for bonding light alloys in aircraft production, current applications range from the bonding of tungsten carbide cutters to mild steel mounts to the joining of steel shafts to wood badminton rackets. A wide range of adhesives is now available suitable for different applications.

Adhesion is due to intermolecular forces, and hence the object in formulating an adhesive is to secure good wetting characteristics. For this reason, also, the strength of the joint is generally considerably reduced at elevated temperatures. It is usually not greatly affected, however, at reduced temperature down to −4° F. A disadvantage which is characteristic of the adhesives used is that the impact strength of the joint is low. The fatigue strength is good, and is often superior to that of spot welded or riveted joints.

The area of the joint must be large, and this requirement is best met by a type of lap joint. The adhesive is then stressed in shear. Increasing the length of overlap does not necessarily directly increase the joint strength. Joint geometry and the thickness and properties of the

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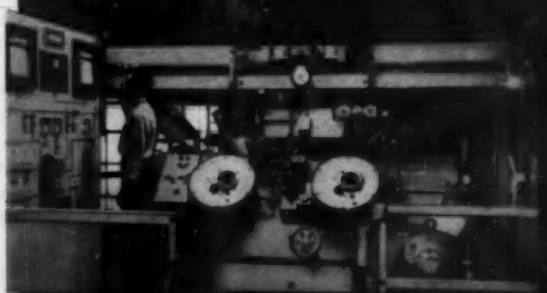

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Job Report Courtesy of Newport News Shipbuilding and Dry Dock Company

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To simplify and speed joining the halves of this pressure vessel shell, and insure corrosion resistant root passes, a preplaced Arcos Consumable Insert was used. With this method, *only outside welding* was required to produce sound welds with uniform contours on the inaccessible inside surface. The welds readily passed Radiograph inspection for freedom from porosity, slag and other inclusions. The EB Weld Insert can save *you* time and money. Write for details. ARCOS CORPORATION, 1500 S. 50th Street, Philadelphia 43, Pa.

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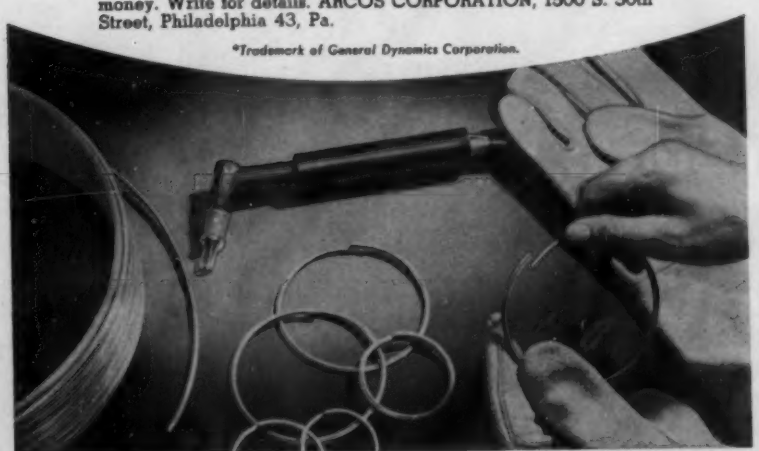


Adhesive Bonding . . .

adhesive all influence the optimum overlap. Close control of production processes is therefore necessary before design strengths can be guaranteed.

Most adhesives have to be set under pressure and often at elevated temperatures. Hand clamping is satisfactory in some cases but hydraulic presses or autoclaves are frequently required. Hot setting adhesives require either steam or electrical heating. The dies required for hydraulic presses are expensive except for simple shapes and it is then that autoclaves are useful.

L. E. SAMUELS

Blanking and Forming Titanium

Digest of "Blanking and Forming Titanium", by W. A. Mays and G. J. Matey, presented at Titanium Conference, Western Metal Congress, March 1957, 10 p.

WHEN THIS PAPER was given, the use of titanium at North American Aviation had steadily increased, and in a representative month of 1956, a total of 68,000 lb. of titanium sheet material was used to make a total of 86,000 parts. Many specialized devices and unique methods had to be developed for blanking, forming, and processing the material.

Forming Properties – As an aid in tool design, equipment selection and manufacturing control, a knowledge of the mechanical properties of titanium is necessary. Alloy titanium containing 8% Mn has a much higher yield strength than annealed 7075 aluminum alloy or 17-7 PH stainless. At the same time, the workability range, defined as the range between yield strength and ultimate strength, where plastic deformation occurs, is much narrower for the titanium alloy.

Elongation, both uniform and total, is another important determining factor in making parts, particularly in stretch forming. Commercial titanium alloys (available at the time of publication of this report) have relatively low elongation, which, with the narrow workability range, imposes limitiations on form-

ing. New heat treatable titanium alloys are being developed which should alleviate some problems.

Nonuniformity of titanium sheet products also creates forming problems. Variations occur in:

1. Directional properties: Titanium often exhibits considerable anisotropy. In addition, properties may vary within a sheet.

2. Gage variations: Variation in gage for titanium alloy from sheet to sheet and within sheets is greater than for other materials. In making parts with matched steel dies, undergage sheets will not form to the proper degree, and high-gage sheets gall or break dies.

3. Surface condition: Grinding scratches or surface scale tends to crack on formed bend radii, causing part failure if not removed.

4. Flatness: Guaranteed flatness is not better than 3% on 0.025 gage and heavier material. "Canned" or waved sheets have nonuniform forming properties.

Quality Control – The functions of the quality control group at North American Aviation include:

1. Quality control of incoming material: All incoming materials are inspected for conformance to a company specification for chemistry, mechanical properties, gage, surface condition, and bendability. Transverse samples from each alloy sheet are preshipped from the mills, and conformance tests are usually complete by the time of receipt of the sheets. Hydrogen content is determined. The percentage of high-hydrogen sheets (over 150 ppm.) has dropped to 1%.

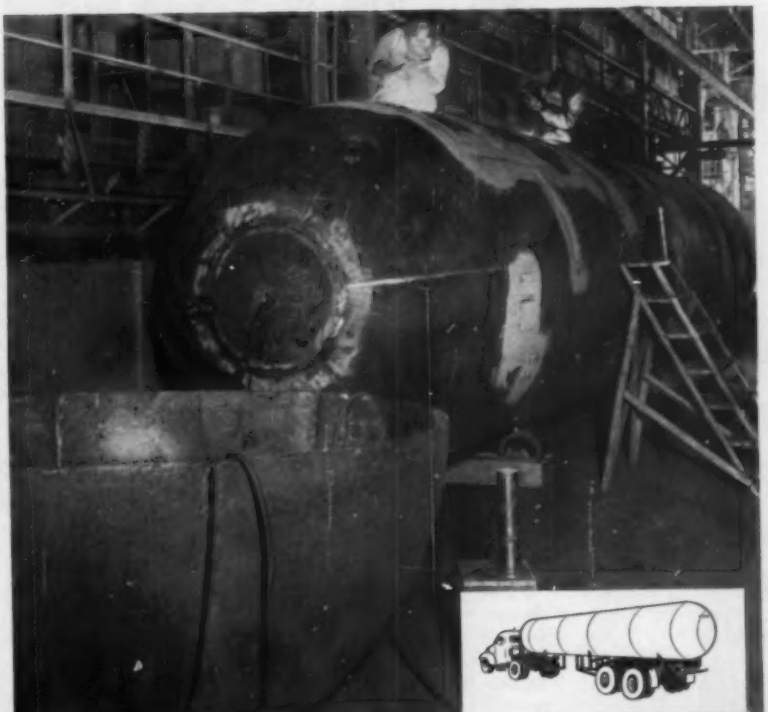
2. Quality control of processing: Accurate control is maintained on all furnaces and pickling baths. Fluorescent penetrant inspection is used to check for cracks in formed parts, and defects are removed by filing or grinding.

As a result of rigorous quality control procedures, the rejection rate on titanium parts has been drastically reduced, and approaches that for other structural materials.

Fabrication Methods – The peculiarities of titanium make necessary the use of unique methods for successful fabrication, and a number of successful techniques have been developed at North American.

Prior to any forming operation, blanks must be properly prepared.

How X-Ray Quality Welds Make Low Alloy Steels Pay Off



Job report courtesy of
Superior Tank & Construction Co., Los Angeles, Calif.

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The vessel being welded is part of an L.P.G. tank truck. For high strength with low weight—USS "T-1" steel is used and welded with Arcos Ductilend 110 Electrodes. These tanks meet or exceed ASME code requirements . . . and all Ductilend 110 welds qualify with X-ray soundness. Ductilend 110 is an Arcos Low Hydrogen Electrode especially developed for welding high strength notch tough steels of the 110,000 psi tensile strength range. Data sheet on request. ARCOS CORPORATION • 1500 South 50th Street, Philadelphia 43, Pa.

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W-L DETROIT The new, larger warehouse and office here have greatly speeded up delivery on our orders and services in this area. Have a good stock of A-8620 on hand as well as all HY-TEN grades.

W-L CLEVELAND The rolls for this Vaughn Four-Roll Continuous Pointer are fabricated from HY-TEN "M" Temper, nickel-chromium-molybdenum oil hardening steel. This Pointer, largest of its type in the world, can point rods ranging from ½″ to 1¼″ dia. HY-TEN "M" was selected by the machine manufacturer because it can be quenched and tempered to high hardness levels while retaining considerably greater toughness than would be possible with most other steels.

W-L CINCINNATI Another new and larger warehouse recently opened here. Same-day service on all sizes, shapes and grades of HY-TEN, plus our usual help on metallurgical problems.

W-L HILLSIDE, N. J. This W-L warehouse has an excellent stock of HY-TEN "B" No. 3-X in rounds, flats and squares. Same-day delivery is promised. Many of the larger sizes of forged rounds are rough turned.

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Titanium . . .

Shearing, slitting, blanking in crank presses, and hand nibbling are all employed, but in each case the edges are worked smooth and free of burrs, nicks and shear cracks. A new method (patented) called "roll blanking" has developed. Excellent light-gage blanks are produced by placing large sheets over special clicker dies and passing them under a heavy roll.

Major Forming – The majority of aircraft titanium parts are used for outside skins or supporting structural members, requiring close tolerances. To meet them, some intermediate shape is usually formed by conventional means, and parts are then hot creep formed to finish shape.

Power brake forming is not difficult, provided bend radii are adequate. At one time the blanks were heated before forming, but much of the work is now done at room temperature. Difficult to stretch parts may require heated tooling (400° F.), and at times partial forming, annealing (1000° F. for ½ hr.) and stretching. The "net die technique" is used on the most difficult to form section stretch parts. This involves overforming, annealing, and restretching on a net die, followed by hot creep forming on hot straightening fixtures.

Modest double-contoured skins are stretch-formed on Hufford or Erco machines, using heated Kirksite dies, and finish formed and stress-relief annealed in the hot straightening machines.

The Oliver stretch creep forming machine makes possible the finish forming and stress-relief annealing of severe double-contour skins in one operation. Resistant heated dies and high-temperature lubricants are used.

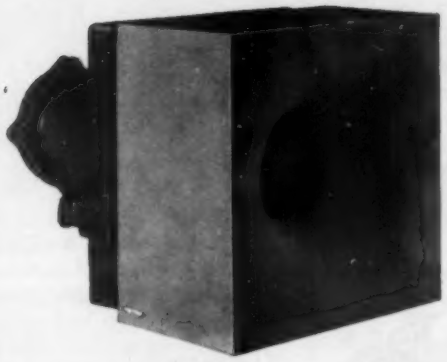
Drop hammer forming is used extensively for severe contoured parts, employing heated blanks, progressive die staging, closely matched Kirksite dies and punches, and interstage annealing.

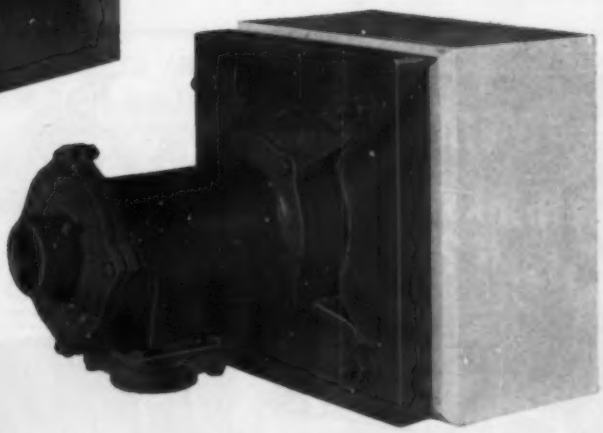
Cincinnati hydroform machines are used to make flanged cups, tubular parts, deeply recessed parts, and flat parts with severe shrink flanges. Finish forming is done in a hot straightening machine.

The Guerin process, shaping blanks over hydropress dies by the

North American

FLAT FLAME BURNERS





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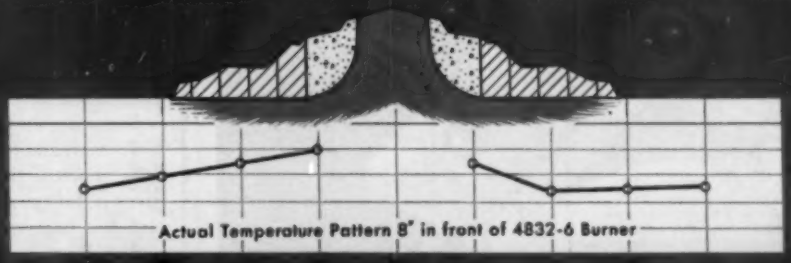

Actual Temperature Pattern 8" in front of 4832-6 Burner

For engineering information consult your nearby N. A. office or write for Bulletin 4832 ▼

The North American Manufacturing Co.
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4832

Titanium . . .

squeezing action of an incompressible rubber pad, is employed to produce a wide variety of single and double-flanged contoured frames and longerons. Most of these parts require finishing by hot creep forming.

Finish Forming – Parts in which a relatively small amount of metal movement is required to finish are final formed in hot straightening fixtures, using net punches with no means of maintaining constant pressure as the metal relaxes. Wavy sheets are flattened by locking four or five between 3-in. thick steel plates and heating to 1000° F. for ½ hr. Parts that require more metal movement are finish formed by hot straightening on hydraulic presses, using heated dies maintained at pressure during forming. In hot straightening machines – the third type of hot creep forming device – stress-relieved parts are placed cold on hot tooling, which is maintained at 1000° F. during the entire run. Some may be operated as three separate machines for small parts, or as a single unit for large parts.

In general, titanium sheet metal can be formed accurately in volume production for airframe components, but the costs are higher than for other more common structural metals. Much development work remains to be done.

WILLIAM V. WARD

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Nozzle Sizes for Rimmed Steel

Digest of "Effect of Nozzle Size on Pouring Rates and Slab Surface of Rimming Steels", by A. T. Peters, Inland Steel Co., East Chicago, Ind. Paper presented at the A.I.M.E. Open-hearth and Blast Furnace Conference, Cleveland, April 1958.

POURING RATES primarily depend upon two factors: (*a*) the constantly dropping ferrostatic head, and (*b*) the constant enlargement of the nozzle through erosion. Since little can be done about the ferrostatic head, all efforts at varying the pouring rates were achieved by varying the nozzle sizes. Standard fireclay nozzles – 2, 2½, 3 and 4 in. in diameter – were used in the experiment. The surface quality of nearly 11,000 slabbed ingots was visually rated at the blooming mill, some heats being followed to final sheet inspection.

Obviously, pouring rates increased and pouring times decreased with increases in nozzle size. The greatest advantages were realized from the use of 3-in. nozzles; 4-in. nozzles filled small ingots so rapidly that rimming agents and aluminum could not be added properly. Since this rapid filling also was a safety hazard, consideration of 4-in. nozzles was dropped early in the investigation.

The 3-in. nozzles, aside from pouring heats more rapidly – and thus improving pit operations – made it possible to produce sheet of better surface quality. Apparently, the surging of the swift stream provided a washing action which cleaned solidified scabs from the mold surface as the metal level rose. Consequently, 3-in. nozzles are now in standard production use for the pouring of low-carbon rimmed steels.

Summing up the main findings:

1. Increasing the nozzle size to 3 in. shortens the pouring time and gives a better pouring rate pattern and less heat-to-heat variability.

2. A drop in pouring rate toward the end of the heat can be compensated for by using smaller molds; an over-all improvement in surface quality results.

3. Increasing the nozzle size improves the over-all slab surface quality; the greatest improvement is noted in ingots from the largest molds. Sheet surface quality was also improved. C.R.W.

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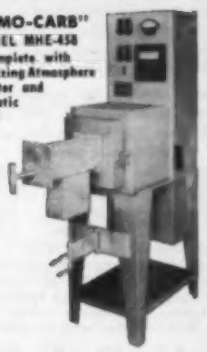

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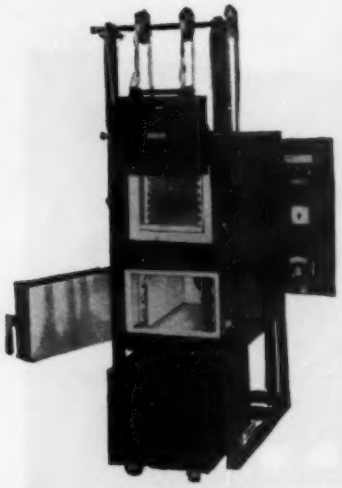

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Drawing furnace has a maximum of 800° F.* Quench tank included with the exception of the largest standard model.

	Chamber Size			Prices	
Model	H.	W.	L.	2000° F.	2300° F.
8055 A	6"	x 6"	x 12"	$ 865.00	$ 975.00
8055 B	9"	x 9"	x 18"	1325.00	1450.00
8055 C	12"	x 12"	x 24"	1850.00	1950.00
8055 D	18"	x 18"	x 36"	2750.00	2875.00

*Also available up to 1250° F.

WRITE FOR FREE LITERATURE, SPECIFICATIONS and price list of Lucifer Furnaces in wide range of sizes—top loading and side loading types. Engineering advice without obligation. Write, wire or phone today.

LUCIFER FURNACES, INC.
NESHAMINY 7, PA.
Phone: Diamond 3-0411

LIST NO. 122 ON INFO-COUPON PAGE 168

PACIFIC FURNACES ARE ENGINEERED FROM THE INSIDE OUT

Pictured is a Pacific Air Draw Furnace currently drawing and tempering 3000 lb. of pearlitic malleable iron castings per hour at a leading foundry. This Pacific engineered furnace features hydraulic pushers, three-zone automatic cycling, and automatic unloading at the completion of the operation. It operates at 1400° F.

Pacific ENGINEERS . . . . BUILDS . . . . SERVICES all types of industrial heating equipment.

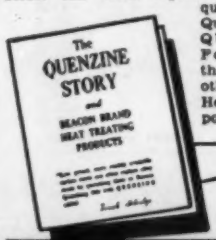
FOR COMPLETE INFORMATION ON OUR SERVICES —WRITE OR CALL

THE Pacific INDUSTRIAL FURNACE CO.
24680 Telegraph Road, Detroit 19, Michigan
Phone: Kenwood 3-6900

LIST NO. 173 ON INFO-COUPON PAGE 168

FREE
the QUENZINE STORY

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



ALDRIDGE INDUSTRIAL OILS, Inc.
3401 W. 140th St., Cleveland 11, Ohio

LIST NO. 29 ON INFO-COUPON PAGE 168

END POT FAILURE

Switch to *scheduled* pot maintenance with low-cost pressed-steel pots for lead, salt, cyanide, oil-tempering, metal-melting. Can't turn suddenly defective, because no faulty steel survives drawing. Request catalog from Eclipse Fuel Engineering Co., 1127 Buchanan St., Rockford, Ill.

Eclipse INDUSTRIAL COMBUSTION DIVISION

LIST NO. 176 ON INFO-COUPON PAGE 168

HEAT TREATING
EQUIPMENT
Stanwood is one of the oldest organizations devoted to the design and manufacture of heat treating equipment exclusively for heat treaters and metal working plants throughout the nation.
Stanwood has the experience, the organization and the facilities.
Representatives in major cities, Send for Catalog.
STANWOOD CORPORATION
4817 W. CORTLAND STREET CHICAGO 39, ILLINOIS

LIST NO. 12 ON INFO-COUPON PAGE 168

STEEL FABRICATED and RUBBER-LINED TANKS for the Plating Industry

ARco

- Plating tanks any size or shape fabricated and rubber-lined to your specifications. A complete service from basic design to installation, also fabricated and rubber-lined pipe and fittings. Write Dept. "MP" for complete details.

Subsid. of Automotive Rubber Co., Inc.

ARco STEEL FABRICATORS • INC.
12542 BEECH ROAD • DETROIT 39, MICH.

LIST NO. 153 ON INFO-COUPON PAGE 168

WIRETEX *fabricated*

PLATE POTS

Last longer.... cut operating costs
fast delivery..low cost

WIRETEX PLATE POTS withstand temperatures up to 2100°! Cut neutral or cyanide bath costs! Last 15 to 20% longer! Operating costs drop 25 to 35%! Down time is almost halved!

- All metals
- I.D. dia. up to 24" and larger
- Depths unlimited
- Dished bottom heads
- Overlapping seams
- Double x-ray quality weld, inside and out
- Heavy steel flanges
- Stress relieved
- Sand-blasted finish

Before you buy any salt pot, or if you have other heat and corrosion resistant problems —SEE WIRETEX.

Before you buy any salt pot, or if you have other heat and corrosion resistant problems—SEE WIRETEX.

Wiretex mfg. co. 5 Mason St., Bridgeport 5, Conn.
Specialists in Processing Carriers Since 1932

LIST NO. 114 ON INFO-COUPON PAGE 168

RUST-LICK IN AQUEOUS SYSTEMS

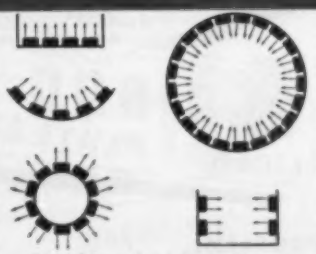
Eliminates RUST
&
Fire Hazards
Non-Flammable
Non-Toxic

Send for Brochure:
The ABC of Rust-Lick for Rust Prevention

PRODUCTION SPECIALTIES, INC.
755 BOYLSTON STREET
BOSTON 16, MASS.

LIST NO. 105 ON INFO-COUPON PAGE 168

ULTRASONIC CLEANING



Typical Transducer Arrangements

SONOGEN®

Ultrasonic-Power Generators with hermetically-sealed barium-titanate Transducers — 40Kc/sec.

Transducer Radiating Areas of ¼ sq. ft. to 10 sq. ft. — for use in solvents and detergents.

Eliminates hand operations — Reduces rejects in plating, finishing, assembly.

For washing, degreasing, removal of buffing compounds, radioactive contamination, soldering flux, plaster, carbon smut, etc.

Literature upon request.

BRANSON ULTRASONIC CORP.

Specializing in Ultrasonics Since 1946

4 BROWN HOUSE RD., STAMFORD, CONNECTICUT

LIST NO. 81 ON INFO-COUPON PAGE 168

WANTED

SIR PLUS FURNACES

REWARD

WE PAY CASH FOR SURPLUS INDUSTRIAL FURNACES AND RELATED APPARATUS

SURPLUS FURNACES FOR SALE

BOX TYPE

24x36x18	Lindberg	50KW	2000°F
36x72x23	G.E.	72KW	2000°F
48x84x24	American	100KW	1850°F
24x36x14	Surface	Gas	1850°F
54x96x24	Surface	Gas	1850°F

PIT TYPE

20x22	G.E.	48KW	1200°F
28x28	Lindberg	52KW	1250°F
48x72	Lindberg	Gas	1250°F
48x96	Surface	Gas	1250°F
48x96	Lee Wilson	Rad. Tube	1850°F

CONVEYOR TYPE RECIRCULATING

72x40'x30	Surface	RlrHrth Gas	1250°F
27x15'x12	R&S	MshBlt Gas	1250°F

BOX TYPE RECIRCULATING

6'x12'x42"	Lindberg	Gas	1250°F
66"x16'x76"	Lindberg	180KW	1250°F
60"x10'x42"	Lindberg	180KW	1250°F
42"x16'x30"	Lindberg	120KW	1250°F

BOX & CONVEYOR OVENS

6'x30'x18"	Mich Oven Conv	150KW	550°F
6'x30'x18"	Mich Oven Conv	150KW	400°F
5'x16'x12"	Mich Oven Conv	150KW	800°F
2'x2'x4'	Rockwell Box	5KW	550°F
7'x7'x7'	Young Bros Box	Gas	650°F
19"x19"x19"	Despatch Box	5KW	850°F

BRAZING TYPE

18"x42"x12"	Lindberg Pshr	60KW	2500°F
18"x42"x10"	Westinghouse Pshr	50KW	2050°F
62"x18'x24"	GE RlrHrth	655KW	1650°F

SEND FOR COMPLETE LIST

THE JOE MARTIN CO., INC.

19256 John R. St. TWinbrook 2-5500 Detroit 3, Mich.

LIST NO. 160 ON INFO-COUPON PAGE 168

Sel-Rex®

PRECIOUS METALS FOR INDUSTRIAL PLATING

BRIGHT GOLD

Mirror-bright finish in any thickness directly from the bath. Patented

PUR-A-SALTS

Restores contaminated cyanide plating baths to full, trouble-free operation. Patented

SILVREX BRIGHT SILVER

Crystal-clear solution that produces mirror-bright deposits. Patented

SILVER SOL-U-SALT

Non-dusting — safest and easiest to use.

BRIGHT RHODIUM

Brilliant, fine-grained non-tarnishing deposits.

RHODEX

Only rhodium electroplating process that yields extra heavy compressively stressed deposits. Patent Pending

ACID GOLD PLATING PROCESS

Developed specifically for plating printed circuits. Mildly acid so that neither the laminate nor the adhesive at the inter-face of printed circuit boards are affected during the plating process.

Complete installation and servicing on all precious metals processes.

SEL-REX CORPORATION

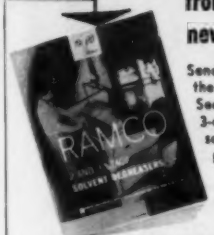
Dept. BB, Nutley 10, New Jersey

Offices: Detroit, Chicago, Los Angeles

LIST NO. 108 ON INFO-COUPON PAGE 168

Q A METAL PARTS CLEANING PROBLEMS?

Get the answers RIGHT from RAMCO'S new BULLETIN!



Send for your copy of the Ramco Bulletin. See how Ramco 2- and 3-dip degreasers can solve your metal parts cleaning problems, economically, efficiently, safely! Write today!

RAMCO EQUIPMENT CORP.

DIV. OF RANDALL MFG. CO., INC.

809 Edgewater Rd., New York 39, N.Y.

LIST NO. 128 ON INFO-COUPON PAGE 168

How Roll Coater

Pre-Painted

METAL SAVED MONEY AND IMPROVED QUALITY ON

R-C-000 LICENSE PLATES

PROBLEM:

Stello Products Company, Logansport, Indiana, manufacturer of tags, license and "booster" plates, had the problem of excessive direct labor charges. In the previous expensive method of making these items, plates had to be stamped from bare metal —and then cleaned individually—and spray painted on both sides. This method did not give the uniform quality demanded—and Stello turned to Roll Coater for a solution.

SOLUTION:

Roll-coated metal was tested by Stello Products Company. *Pre-painted* and *baked* on both sides, this metal eliminated *entirely* the cleaning and spray painting operations—withstood rigorous stamping tests—and relieved painting facilities for other jobs. Says J. C. Cotner, president of Stello Products Company, "Roll Coater metal is now saving us approximately 50% in direct labor costs—and is giving us the desired uniform quality in our plate production. It really solves our problem."

SEND FOR FREE BROCHURE and SAMPLE TODAY!

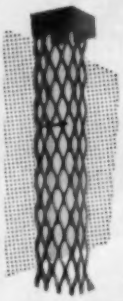
Roll Coater

INCORPORATED

PENDLETON INDIANA

LIST NO. 155 ON INFO-COUPON PAGE 168

there's a *Glo*-QUARTZ* IMMERSION HEATER for Your Every Heating Requirement



- INSTANT HEATING
- SHOCK-PROOF
- AVAILABLE IN ALL VOLTAGES —WATTAGES, ONE AND THREE PHASE

Available from your Electroplating Distributor

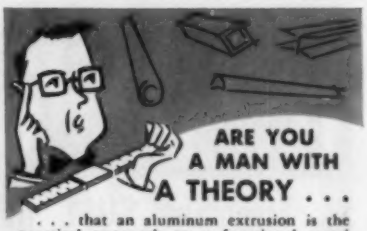
WRITE FOR BULLETIN ▶

Glo-QUARTZ*

ELECTRIC HEATER CO., INC., Willoughby, Ohio

*Reg. U.S. Pat Off. Phone: Willoughby 2-5521

LIST NO. 145 ON INFO-COUPON PAGE 168



ARE YOU A MAN WITH A THEORY . . .

. . . that an aluminum extrusion is the practical approach to a functional metal parts application . . . at a savings in time and money, and without loss in quality? In fact, the properties — you theorized — of extruded aluminum would even be better? If so, G.E.I.'s engineers are ready to consult with you — without obligation, on one part or a million — to determine how practical your idea is. G.E.I. engineers specialize in adapting extruded aluminum to *new* functional roles.

GENERAL EXTRUSIONS, INC.

4649 LAKE PARK RD., YOUNGSTOWN, OHIO STerling 8-9681

Missouri, S. Illinois Representative: Frank Metz Co., 4378 Linden Blvd., St. Louis 8, Mo.

Michigan Representative: Howard B. Jones, 15842 Kentfield Ave., Detroit 23, Mich.

Southern Distributor: General Extrusions of Memphis, Inc., 4462 Seamor Ave., Memphis, Tenn.

LIST NO. 141 ON INFO-COUPON PAGE 168

ARco AIR WASH SYSTEMS

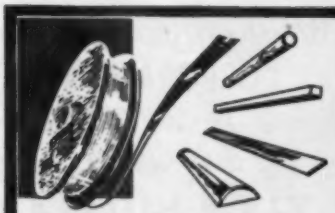
PLATING • PICKLING • METAL CLEANING *FUME SCRUBBING*

• Reasonable initial cost . . . economical in operation . . . no moving parts . . . efficient in performance . . . compact—requires little space . . . standard units—7200 to 57600 C.F.M. Write Dept. "MP" for complete information.

AUTOMOTIVE RUBBER CO. • INC.

12550 BEECH ROAD • DETROIT 39, MICH.

LIST NO. 154 ON INFO-COUPON PAGE 168



ROUND, SQUARE, FLAT AND HALF-ROUND WIRE FOR MASS PRODUCTION OF SMALL PARTS

Beryllium Copper • Bronzes
Other Non-ferrous Alloys
Rounded or square edges.
Available with hot-tinned finish for solderability.
Write for descriptive folder.

LITTLE FALLS ALLOYS
INCORPORATED
193 Caldwell Ave., Paterson 1, N. J.

LIST NO. 66 ON INFO-COUPON PAGE 168

LUBRICATION DATA FOR COLD FORMING OPERATIONS

This technical newsletter is filled with case history reports of successful uses of MOLYKOTE® Lubricants in cold forming operations. A chart shows the metal being formed and the type of MOLYKOTE used together with the proper method of application.

Send for this MOLYKOTE NEWSLETTER today. (Refer to Bulletin 304).

THE ALPHA-MOLYKOTE CORPORATION

Main Factories:
65 Harvard Ave., Stamford, Conn.
71 Arnulfstrasse, Munich 19, Germany

LIST NO. 110 ON INFO-COUPON PAGE 168

A PROVEN DEPENDABLE SOURCE
FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING
Special Feature — Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

ENGINEERED PRECISION CASTING CO.

MORGANVILLE, N. J.

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GET A BID FROM

HOOVER

SPECIALISTS IN THE FIELD OF

Die Castings

SINCE 1922

Aluminum and Zinc

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
In Canada—Hamilton, Ontario

LIST NO. 74 ON INFO-COUPON PAGE 168

PM²=Quality +Economy

in your electroplating of

HARD GOLD

HARD BRIGHT GOLD

SOFT GOLD

PLATINUM

RHODIUM

PALLADIUM

TECHNIC PM² (Precious Metal Plating Metallurgy) ensures Quality and Economy. For electroplating both conventional alloys and exotic alloys such as are required in electronics and atomics, Technic enables you to get predetermined results that are *exactly reproducible*. Our solutions and method give you rigid scientific control of performance and cost, eliminate wasteful deviation from strict standards.

CASE HISTORIES ON RECORD

Case histories illustrate the efficacy of Technic PM². Ask for the names of industrial leaders who lower cost and control quality with Technic precision electroplating.

TECHNIC SERVICE

Besides formulating scientifically correct solutions, we are equipped to install or to modernize all your requirements for precious metal electroplating. No Technic installation is checked out as complete until it achieves optimum performance. Send us your problems — old or new — for recommendations.

120-8

TECHNIC, INC.

39 Snow Street,
Providence, R. I.
JAckson 1-4200
Chicago Office—7001
North Clark Street

THE LARGEST ENTERPRISE OF ITS KIND IN THE WORLD

LIST NO. 147 ON INFO-COUPON PAGE 168

Solve
Inspection
Sorting
Demagnetizing
Problems
with
MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT

Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed – 120 ft. per minute.

SPECIAL EQUIPMENT

Electronic equipment for non-destructive production inspection of non-ferrous bars and tubing . . . as well as both non-magnetic stainless and high temperature steel bars and tubing – seamless or welded. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed – 200 ft. per minute.

WIRE ROPE EQUIPMENT

Electronic equipment for inspecting ferromagnetic wire ropes from 1/32" to 3" diameter. Detects broken, cross-over or missing wires, plus defective welds and deformations at production speeds up to several hundred feet per minute.

COMPARATORS AND METAL TESTERS

Electronic instruments for production sorting of both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

DEMAGNETIZERS

Electrical equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETISM DETECTORS

Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

"THE TEST TELLS"
For Details Write:
MAGNETIC ANALYSIS CORP.
42-44 Twelfth St., Long Island City 1, N. Y.

LIST NO. 51 ON INFO-COUPON PAGE 168

ARC ETCH ANY METAL
OF ANY HARDNESS—Quickly—Easily
WITH THE
ACTOGRAP PEN

Only the ACTOGRAP metal etching pen has all of these features:
- Freedom from mechanical vibration
- Short, powerful, continuous arc—will etch hardest metals rapidly
- Does not heat up
- Light and small—can be used like a fountain pen
- Operates optionally on battery or conventional AC current
- Depth of etch can be regulated by an exclusive selection switch

only $49.50 with transformer

WRITE, WIRE, OR CALL FOR DETAILS

NEWAGE INDUSTRIES, INC.
222 York Road
TUrner 4-8494
Jenkintown, Pa.

LIST NO. 180 ON INFO-COUPON PAGE 168

Measures Nonmagnetic Coatings with ±5% ±.0001" accuracy

NEW pocket-size Thickness Gauge

ELCOMETER measures thickness of porcelain enamel, paints, platings, foils, glass, paper, plastics, and other nonmagnetic coatings quickly and accurately. Gauges flat or curved surfaces and hard-to-get-at spots easily. Needle locking device assures correct reading every time. Complete with tough leather case containing inner pocket for test strips. Weighs only 6 oz. Completely self-contained.

FREE TRIAL. Ask your purchasing agent to order an Elcometer on trial basis. Retail price, F.O.B. Cleveland.

ONLY $75.00

FERRO CORPORATION
4155 East 56th Street
Cleveland 5, Ohio

LIST NO. 148 ON INFO-COUPON PAGE 168

HAWKRIDGE METALS CORPORATION

Producers and Sellers of
(VIRGIN)

TITANIUM POWDER

—20 to +200 mesh

Both HIGH PURITY and COMMERCIAL grades available.

North Hampton
New Hampshire

LIST NO. 177 ON INFO-COUPON PAGE 168

TENSILKUT

Tensile and fatigue test specimens can be accurately machined from foil metals as light as .0005" or heavy .500" plate in less than two minutes. Machined edges are completely free of cold working and the specimen configurations are duplicated within ± .0005".

TensilkuT machines a wide range of metals including steel, aluminium, stainless steel, copper, titanium, uranium, lead, the super alloys and all plastic materials.

Tensilkut table and floor models are available with motors from ⅛ to 2½ HP. Write for our latest brochure.

Trade Mark Registered U.S. Patent Office
Patents Pending United States & Canada.

SIEBURG INDUSTRIES
INCORPORATED
HORSE PLAIN ROAD • NEW BRITAIN, CONN.

LIST NO. 131 ON INFO-COUPON PAGE 168

HARDNESS TESTING
SHORE SCLEROSCOPE

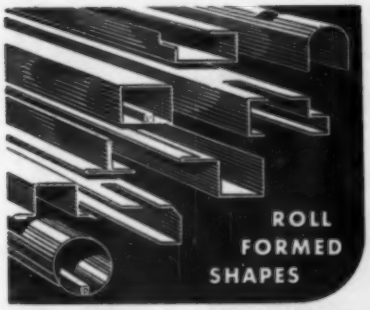
Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

SHORE INSTRUMENT & MFG. CO., INC.
90-35M Van Wyck Exp., Jamaica 35, N.Y.

LIST NO. 133 ON INFO-COUPON PAGE 168



Reduce your assembly problems and costs. Our shapes continuously formed, with high degree of accuracy, from ferrous or non-ferrous metals. Write for Catalog No. 1053.

ROLL FORMED PRODUCTS CO.

MAIN OFFICE AND PLANT
3761 OAKWOOD AVE. • YOUNGSTOWN, OHIO

LIST NO. 101 ON INFO-COUPON PAGE 168

KENTRON

MICRO
HARDNESS TESTER

Applies 1 to 10,000 gram loads

Write for Bulletin

Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

LIST NO. 53 ON INFO-COUPON PAGE 168

A CABLE SPLICED IN 10 SECONDS!

ERICO PRODUCTS, INC.
Complete Arc Welding Accessories
2070 E. 61st Place, Cleveland 3, Ohio
Write for Caddy Catalog

LIST NO. 71 ON INFO-COUPON PAGE 168

THE NEW
DERMITRON

NON-DESTRUCTIVE COATING THICKNESS TESTER

FAST... ACCURATE NON-DESTRUCTIVE DIRECT-READING

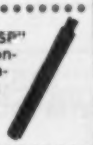
- Instantly measures the thickness of metallic and non-metallic coatings and films
- Based on eddy-current principles
- Enables measurements on small or otherwise inaccessible areas

This portable instrument for both laboratory and production use, gives fast, accurate and direct readings of virtually any coating on any base, including:

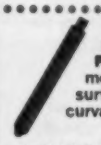
- Metal coatings (such as plating) on metal base (magnetic and non-magnetic)
- Non-metallic coatings (such as paint, anodizing, hard-coat, ceramic) on metal base
- Metal films (such as vacuum metalizing) on non-metallic base (plastics, ceramics)

MEASURING PROBES ARE AVAILABLE IN THE THREE TYPES SHOWN BELOW

NEW RIGHT-ANGLE PROBE model "RP" enables measurements in holes down to ½" I.D.



STANDARD PROBE model "SP" enables measurements on convex surfaces down to ⅛" radius of curvature and on concave surfaces down to 2" radius of curvature



MODIFIED STANDARD PROBE model "MP" enables measurements on concave surfaces down to ¼" radius of curvature

Each of the above probe types is available in 4 different thickness ranges—A, B, C and D, from thick to thin deposits.

Write for latest bulletins and questionnaire to help solve your thickness testing problems

UNIT PROCESS ASSEMBLIES, INC. UPA

LIST NO. 139 ON INFO-COUPON PAGE 168

---

the **GRIES**
MICRO-REFLEX
HARDNESS TESTER

Loads: 10 to 3000 gram with CARL ZEISS Optical System

Measurement: to 0.0001 mm. . . . Observations on Ground Glass . . . Projection: to 0.001 mm. . . . Many Unique, Very Important Features.

INVESTIGATE!
Write for Bulletin No. A-16

GRIES INDUSTRIES, INC.
Testing Machines Division

LIST NO. 135 ON INFO-COUPON PAGE 168

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make hardness tests
ANYWHERE
WITH THE
NEWAGE TESTER

- CLAMPS, JAWS & BASE PLATE ARE ELIMINATED
- NO CONVERSIONS OR CALCULATIONS
- TEST ANY SIZE, SHAPE OR TYPE METAL
- NO SKILL REQUIRED
- SCALE READINGS IN ROCKWELL & BRINELL
- ACCURACY GUARANTEED

Many thousands used by industry and government. Write, wire or call for additional details and prices.

NEWAGE INDUSTRIES, INC.
325 York Road *Jenkintown, Pennsylvania*
TUrner 4-0494 *Dept. MP*

LIST NO. 163 ON INFO-COUPON PAGE 168

Leitz **MINILOAD TESTER**

FOR VICKERS AND KNOOP HARDNESS

STANDARD HARDNESS TESTERS for ROCKWELL and BRINELL TESTS also available.

Request Catalog 72-1

OPTO-METRIC TOOLS, INC.
137 M P VARICK STREET, NEW YORK 13

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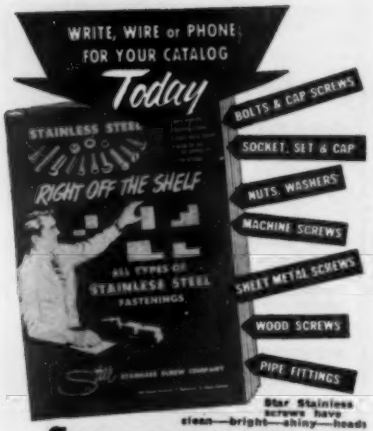

STAR STAINLESS SCREW CO.

CORROSION RESISTANT

647 Union Blvd., Paterson 2, N. J.
Telephone: CLifford 6-2300
Direct N.Y. 'phone Wisconsin 7-9041
Direct Phila. 'phone WAlnut 5-3660

LIST NO. 99 ON INFO-COUPON BELOW

Whitelight MAGNESIUM

your comprehensive independent mill source of magnesium alloy . . .

ALLOYS
AZ10
AZ31
AZ51
AZ61
AZ81
ZK60
ZK30
M-1
ZK-20
Anodes

RODS ⅛" dia. to 6½" dia.
BARS, STRIPS .022" min. to 7½" max.
SOLID SHAPES .022" min. to 8½" circle
TUBING ¼" O.D. to 8" O.D.
HOLLOW SHAPES ½" to 6½" circle
PLATE & SHEET .092" to 3" thick

WHITELIGHT MAGNESIUM

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From Aluminum to Zirconium Lithium Metal has provided the key to discoveries representing a major scientific break-through in light alloy research. These examples attest to the importance of lithium metal as a product improver.

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Niagara Smelt recommends the use of their "FALLS" 5% Lithium Aluminum Master Alloy to reduce porosity in aluminum die casting alloys. Unexcelled as a deoxidizer and degasifier for copper, bronze and bearing alloys is their "FALLS" 2% Lithium Copper. It produces a strong, dense, highly electrically conductive casting. And cuprous oxide in copper and copper-base alloys is best deoxidized with Lithium Copper Cartridges.

Handy & Harman

H. & H. supplies brazing alloys of lithium-silver and lithium-silver-copper for joining stainless steel and titanium alloys. Its strong deoxidizing effect on the oxide coating of the metal increases the alloy's wetting character. Melting point is also reduced, and lithium's self-fluxing effect eliminates the need for chemical fluxes in reducing or inert atmosphere brazing.

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Wall Colmonoy uses lithium metal to braze titanium and zirconium parts. Li in the form of a metal vapor atmosphere is used as a deoxidizer for oxygen, causing good wetting and flow. The brazing is accomplished at 1400-1600°F., remarkable since the melting point of the silver used is over 1700°F. Lithium as a gas flux plates the surfaces with silver, making soldering possible using any standard silver type. The process admirably lends itself to commercially pure titanium where it is necessary to stay under the transformation temperature of Ti.

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Controlled Density Steel

Digest of "The Tensile Strength of Light Steel", by E. W. Williams, *Canadian Mining & Metallurgical Bulletin*, Vol. 50, March 1957, p. 147-153.

"CONTROLLED DENSITY STEEL", so called by the Ontario Research Foundation, is made by a process combining direct reduction of iron oxide powders, sintering (without compaction), and carburizing. In molded products, densities from 1.5 to 5.5 g. per cc. are attainable. Both a super concentrate of magnetite and mill scale were used to produce test specimens for the determination of mechanical properties in a program sponsored by the Defense Research Board. Particle size of the oxides ranged from −60 +400 mesh, with the coarser fractions (−60 +150) being used to produce lower density samples. Tensile strength is the most useful single guide to the practical evaluation of a new material; wherever possible, ten tests were carried out for each combination of conditions, to provide good average values.

Two forms of specimen molds were used for producing test pieces: The first, a 1-in. diameter × 16-in. long cylinder mold, was made either by conventional shell molding techniques (two half molds) or by using a very slightly tapered polished bar as a pattern to make a thin one-piece shell mold. The second was a 0.505-in. diameter, 2-in. gage length tensile-test piece, formed by normal shell molding methods. Molds were filled with iron oxide powder, set in coke breeze in metal saggers, and soaked from 5 to 30 hr. at 1900 to 2100° F. Carbon content and density were varied in the reduced product by using different combinations of feed particle size, coke/oxide ratio, soaking temperature, and heating and cooling times. Low-carbon high-density specimens were produced by decarburizing high-carbon specimens in moist hydrogen. Bars were machined or centerless ground to test size and shape. Heat treatment was done in nitrogen atmosphere, water or oil quenched. Alloying was effected by thorough mixing of the oxide with the alloying element. Density values were determined from weight and volume measurements, or water displacement. Tensile testing was performed

How to measure

Now is the time to take a long, hard look

A continuous furnace is more than just a brick-lined structure built to heat a material; it is a processing tool.

Like all processing tools, it must be evaluated on an overall basis. Fuel consumption and efficiency may be completely outweighed by many more-important economic factors centering around your workpiece, your total production program, and your work force.

Your evaluation may well prove that an investment now in Selas continuous heat processing will bring immediate returns in reduced costs and improved product quality.

To help you take this long, hard look at your heat processing equipment or requirements, Selas offers these 15 evaluation factors:

- **Material saving**
- **Product quality**
- **Floor space**
- **Product value**
- **Work in process**
- **Labor requirements**
- **Process coordination**
- **Maintenance**
- **Material handling**
- **Automatic operation**
- **Temperature control**
- **Production requirements**
- **Equipment flexibility**
- **Fuel efficiency**
- **Human element**

The factual report on the facing page tells how a steel mill took this long, hard look at its forge shop operations. Every evaluation factor proved significant: several represented important savings.

SELAS

the real cost of continuous heat processing

. . . here's how one SELAS installation stands up under that "long, hard look!"

SELAS fast-heating techniques for hot working operations are proving that steel heated rapidly—with no soaking necessary—exhibits improved metal flow beyond that of steel heated slowly and soaked.

This improved forgeability reduces power requirements at usual forging temperatures, or, for a given amount of applied power, permits an increase in degree of deformation; enables working the steel at lower temperatures with no increase in applied work or die wear.

Heating steel billets for forming of special aviation parts and other close-tolerance forgings in a large eastern steel mill, this compact rotary hearth furnace secured important savings in cost, space and labor.

Material Saving

Scale produced during the 11-min heating cycle of a 4-in. square billet, is 0.004 in. thick. This loss in weight is less than 0.25%, compared with 6-8 times that amount when heating to forging temperature in conventional furnaces. At only 1% saving, $1,000 per 40-turn month is recovered—without considering effect upon product quality, machining cost, die wear and similar side effects of excessive scale.

Product Quality

Short cycle heating, to 2250°F in only 11 min produces finer grain, greater forgeability at temperature, improved material flow in the press, and, therefore, a tougher, stronger forging.

Floor Space

The characteristic compactness of Selas high capacity equipment . . . with heat directed into the workpiece, not the work area . . . results in a 60% saving in floor space. Pitch diameter of this 11,000 lb per hr furnace is only 13¾ ft. The smallest conventional furnace offered for this duty had a pitch diameter of 21 ft covering 2½ times as much area as this Selas unit.

Product Value

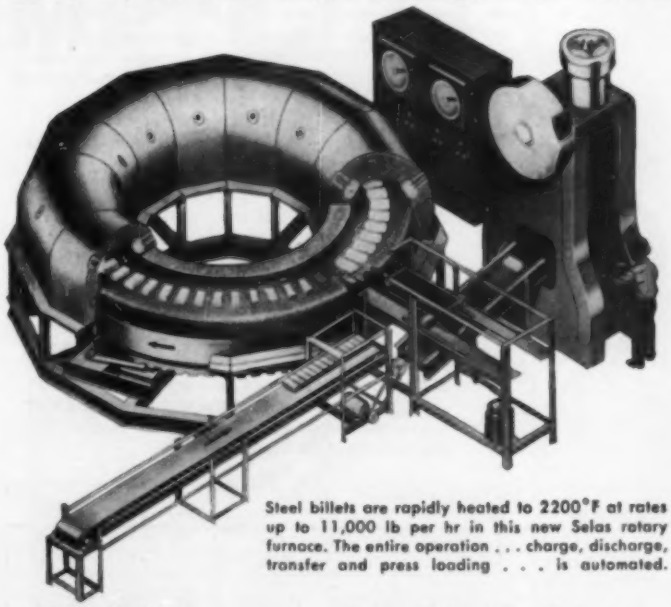
In slightly more than one 40-turn month, the product value of the billets processed equals the cost of the furnace and mechanical equipment.

Work in Process

Less than 1 ton of material is in the furnace at one time, as compared with 11 tons under a conventional 2-hr heating program.

Labor Requirements

Automatic handling of heated billets makes press operation a one-man job—saves $1300 per month.



Steel billets are rapidly heated to 2200°F at rates up to 11,000 lb per hr in this new Selas rotary furnace. The entire operation . . . charge, discharge, transfer and press loading . . . is automated.

Process Coordination

Fitted into the processing line, the furnace forms one important unit, with the press, trimmer and delivery conveyor completing the production picture. The custom-built rotary furnace was shipped from Selas, assembled in sections, and installed with minimum interference to the customer's production operations.

Maintenance

Simple, reliable operating and control equipment, rugged construction, and absence of special atmosphere equipment, simplify routine maintenance. Sectionalized construction will make eventual relining quick and economical. Furthermore, a Selas factory-based service engineer supervised installation and start-up, instructed personnel in operation and maintenance, and is available on call.

Material Handling

Completely automatic for billets weighing up to 55 lb; manual handling is used for heavier billets.

Automatic Operation

Entire heating cycle is automatically controlled, requires only intermittent loading of charge table, occasional check of temperature instruments.

Temperature Control

Billets are delivered metallurgically uniform throughout each billet and from billet to billet.

Production Requirements

The furnace supplies sufficient material for normal press operation with some reserve capacity.

Equipment Flexibility

The furnace heats billets from 3¼ in. square x 5.1 in. long, to 7½ in. square x 24 in. long. Steels handled include types 1030, 4620, 4815 and 8720.

Fuel Efficiency

Fuel cost, without recuperation, averages only 3% of raw material value.

Human Element

The automatic control eliminates variations due to the human element. Also, the furnace and press cycles are synchronized to enable delivery of a properly heated billet to the press immediately as forging of the preceding billet is concluded (in effect, pacing the press operator).

* * *

For case histories covering other steel mill heat processing operations, as well as heat treating, heating for hot working and brazing, send for reprint "An Economic Appraisal of Continuous Heat Processing." Address Dept. 38.

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Heat and Fluid Processing Engineers

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PACKAGED AIR HEATERS by THERMAL

Extreme compactness, high efficiency and versatility of operation are the chief characteristics of the THERMAL Type CA direct fired air heater. Designed around the high velocity THERMAL burner, it normally requires no refractory, since combustion is limited almost entirely to the burner itself. Adding to its versatility, the CA air heater performs equally well on gas, oil or combination firing and can be adapted to all pressure levels.

Type CA direct fired

Type CA air heaters are most frequently sold as "packaged" units complete with all necessary safety and control apparatus. These units will provide outputs ranging from 200,000 BTU/hr to better than 30,000,000 BTU/hr and at temperatures from 300F to 1500F or higher.

TYPICAL SIZES . . .

Listed below are the overall dimensions of a few of the dozens of output, temperature, and flow combinations possible in these heaters. Figures are for atmospheric pressure units. Higher pressure heaters would be smaller.

BTU/hr	AIR FLOW scfm	TEMP. IN °F	TEMP. OUT °F	A ft.	B ft.	C ft.
800,000	1,000	60	750 F	2½	4½	4
2,500,000	5,000	60	500 F	4	7	6
4,000,000	16,000	700	900 F	7	11	8
10,000,000	8,500	60	1,000 F	5½	10	8
15,000,000	10,000	60	1,200 F	6	12	8

Write for Bulletin #112

THERMAL

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Submerged Combustion
Combustion & Heat Transfer Equipment

Light Steel . . .

on Amsler and Baldwin machines.

The main factors affecting the ultimate strength of as-produced controlled density steel are carbon content and density. In a given carbon range, the tensile strength increases parabolically with increasing density. For higher carbon content ranges, the curves are displaced upwards, although at a density of approximately 3.5 g. per cc. the high-carbon steels (0.65 to 1.2% C) become stronger than the very high carbon material (over 1.2% C), due to the presence of excess free cementite in the latter and the increase in notch effect around pores as pore size decreases. The strength versus density curves for controlled density steel are in good agreement with those obtained by Squire for iron powder compacts. At low densities, the actual strength is higher than that predicted by theory, assuming regularly packed spherical particles. This is attributed to the fact that in practice the particles are angular in shape, and bonding occurs at lower densities. At high densities the controlled density material is somewhat weaker than the theoretical strength, due probably to the notch effect of smaller pore sizes.

Quenching increases the tensile strength of the light steel. Oil is the preferred medium, since excessive oxidation occurs in water. The material is extremely shallow hardening, chiefly because of its low thermal conductivity. Soaking temperatures must be kept low to minimize oxidation.

Phosphorus additions result in improved sintering; a phosphide eutectic is formed which increases the bonding area. In low-density samples the tensile strength is increased without an increase in density; in higher density ranges phosphorus causes no strength increase, and severe warpage occurs.

The addition of 2% Ni raises the strength of as-produced specimens, by improving the nature of the bond. However, oil quenched nickel-bearing specimens were of lower strength than their untreated counterparts because of austenite retention in nickel-rich areas. Molybdenum had similar effects. Manganese additions, on the other hand, raised the strength of untreated

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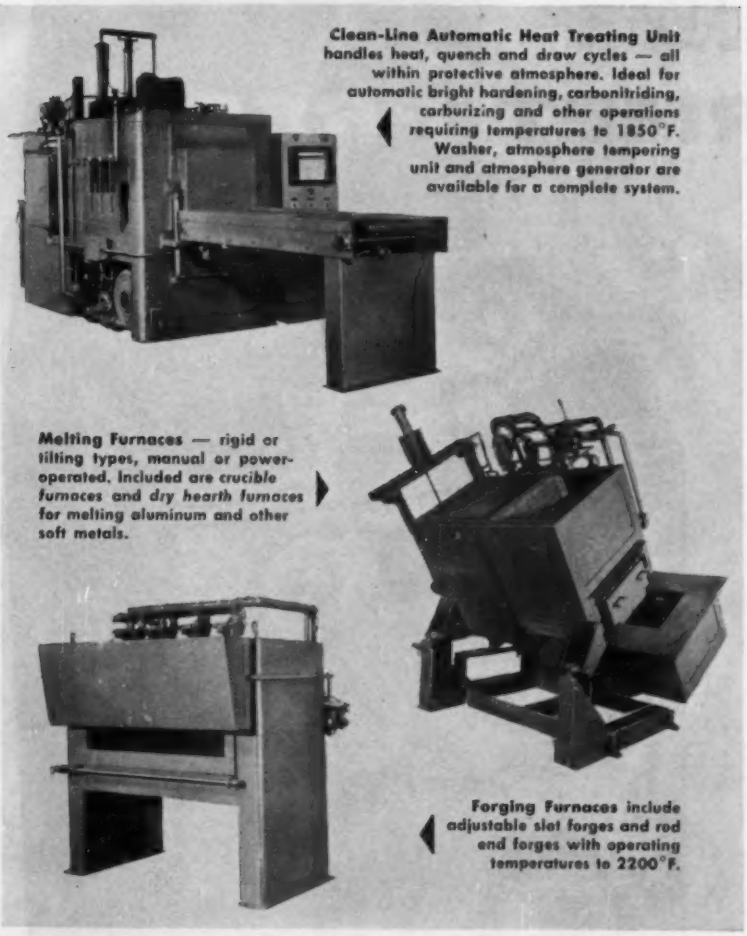
HEVI-DUTY ANNOUNCES
the addition of fuel-fired furnaces to its line



Clean-Line Automatic Heat Treating Unit handles heat, quench and draw cycles — all within protective atmosphere. Ideal for automatic bright hardening, carbonitriding, carburizing and other operations requiring temperatures to 1850°F. Washer, atmosphere tempering unit and atmosphere generator are available for a complete system.

Melting Furnaces — rigid or tilting types, manual or power-operated. Included are *crucible furnaces* and *dry hearth furnaces* for melting aluminum and other soft metals.

Forging Furnaces include adjustable slot forges and rod end forges with operating temperatures to 2200°F.

Hevi-Duty has added to its well-established line of electric heat treating furnaces, a complete range of quality *fuel-fired* furnaces for heat treating, melting and forging, through the purchase of the Industrial Furnace Division of Eclipse Fuel Engineering Company, Rockford, Illinois.

Hevi-Duty will manufacture and sell all types of furnaces formerly built by Eclipse and will provide service and replacement parts for any Eclipse furnaces now in operation.

The acquisition will enable Hevi-Duty to better serve the growing needs for industrial heat. For more information, call your nearest district office or write Hevi-Duty Electric Company, Post Office Box 563, Milwaukee 1, Wisconsin.

- **Heat Processing Furnaces**
- **Dry Type Transformers**
- **Constant Current Regulators**

HEVI-DUTY ELECTRIC CO.
Milwaukee 1, Wisconsin

Light Steel . . .

specimens, and the strength was further increased by quenching, since the microstructure consisted of martensite and sorbite. Manganese, when added as low-carbon ferromanganese, appears to aid sintering. The benefits of alloying additions will be more noticeable in thicker sections. W. V. WARD

Continuous Casting of Steel

Digest of "Continuously Cast Products for the Rolling Mill and Forge", by Josef Hofmaier, *Stahl und Eisen*, Vol. 77, Jan. 24, 1957. p. 69-78.

PROGRESS in the development of the continuous casting process now permits the production of round, square and irregular billets having cross sections up to 133 sq.in.

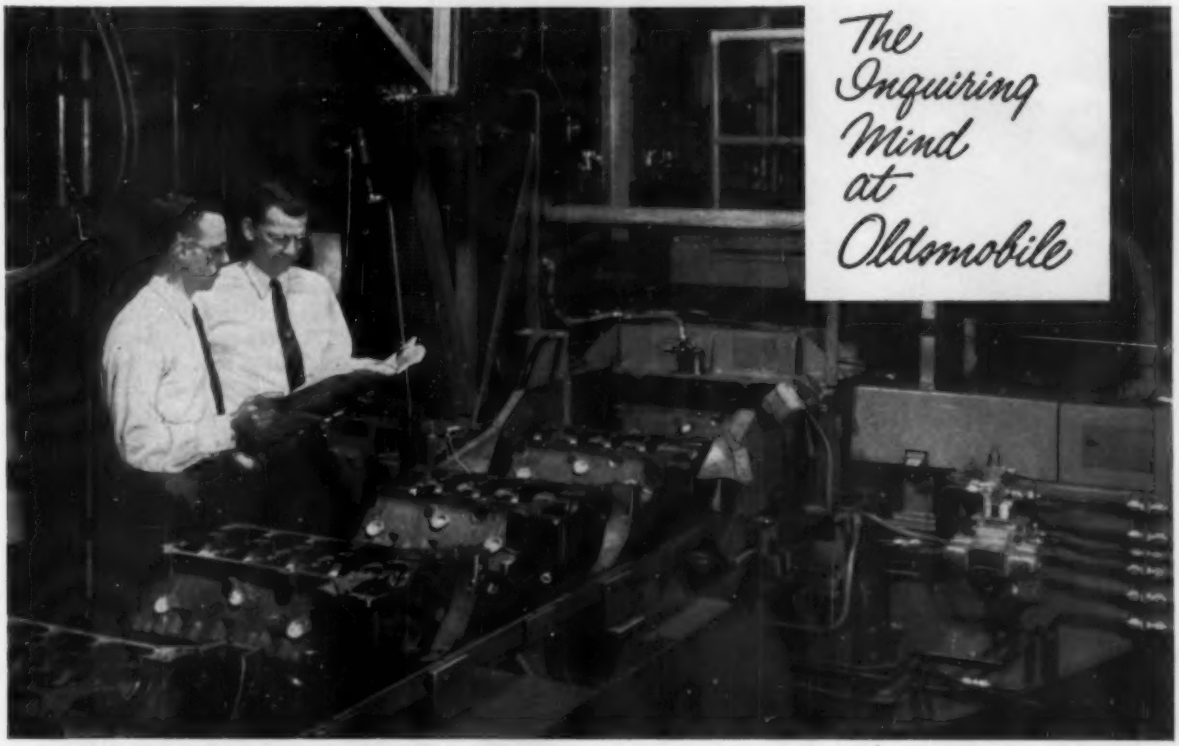
After reviewing the functions of the several parts of the principal operating components, a typical installation is described by the author. The most important locations of continuous casting setups are listed together with typical pouring speeds and production rates attained.

It is of interest to the metallurgist that the surface quality of the continuously cast product is influenced by the pouring velocity. As the speed is increased to a certain threshold value, the surface becomes smoother. At speeds beyond this maximum, hot tears are encountered. Elimination of oxidation by use of a protective atmosphere over the bath, and adequate lubrication of the chill mold are important. The latter aids in the prevention of sticking.

The chemical composition of the alloy cast also affects surface quality, medium chromium - molybdenum steels excelling in this respect.

For the production of finished parts, 4 to 12 passes are generally sufficient. The amount of deformation necessary is a function of the cross-sectional area and chemistry and shape of the continuously cast stock. Usually only localized scarfing or grinding is required to eliminate surface defects.

The quality of continuously cast steel compares favorably with that of ingots. It is uniform throughout the interior zones, and the material



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Automatic camshaft assembly machine assures bearing surfaces so perfect that every Oldsmobile camshaft can be turned by hand.

Installing a camshaft in an engine is like threading a needle. In the hand assembly of this critical part, the cam lobes often score the bearing surfaces. This results in high friction that will 'freeze' a camshaft so that it can be very difficult to turn manually. Olds engineers, however, have developed the only automatic camshaft assembly machine in existence. It installs camshafts so precisely that every one can easily be rotated by hand . . . a guarantee of unmarred cam lobes, less friction and *longer bearing life!*

To go one step further in eliminating any possibility of damaged cam lobes and journals, all handling is done entirely by mechanical means. After grinding, polishing and washing, camshafts are fed by conveyor to the installation machine and mechanically loaded. As the camshaft is properly installed and located in the engine block, a uniform protective coating of oil is applied for proper lubrication before the engine is ever started. So precise is this machine that cam bearings are never touched by the lobes or journals passing through even though clearances are as low as 0.0015 inches.

Attention to small, frequently hidden details is the true mark of quality craftsmanship. At Oldsmobile, quality is not "What will pass?", but rather, "Is this the *best* way to build automobiles?". It is this search for better ways to make better automobiles that makes Oldsmobile distinctive—a car in a class by itself. Discover the difference for yourself. Your friendly Oldsmobile Quality Dealer has a test drive reserved especially for you.

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Scarred lobe on camshaft ▶ indicates scored bearing and may result in shorter camshaft and bearing life.

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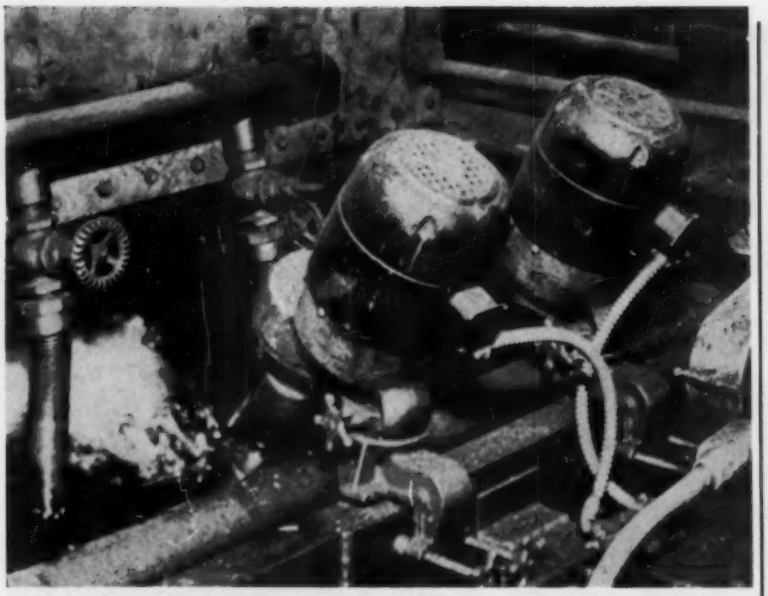

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Often used as a component of new quench tanks and heat treating furnaces. Sizes ¼ to 3 HP.

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These LIGHTNINSs fit existing tanks and adjust easily to the best angle for uniform turbulence. Thirty models; sizes ⅛ to 3 HP.

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For large quench tanks; single or multiple installation. Sizes 1 to 25 HP.

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Continuous Casting . . .

does not exhibit primary or secondary pipes. Porosity is virtually absent if the best operating conditions are scrupulously maintained. With respect to segregation, the continuous casting process is similar to the stationary ingot process: the larger the cross-sectional area, the more segregation may be expected. However, for sheet, wire and rods all quality requirements can be met.

Shrink cracks have not been entirely overcome. They are transcrystalline in nature, and their incidence increases with increasing cross section of the cast shape. Only very high rolling temperatures will heal these discontinuities. High-alloy steels are most sensitive to this defective condition.

High-alloy chromium-nickel and unalloyed toolsteels have shown a tendency toward center-line porosity, unless hot deformation is very uniform and severe. The author has included a number of representative photomicrographs depicting carbide distribution, internal soundness and general microstructure. Generally speaking, the grain size is smaller in continuously cast billets than it would be in conventional ingots. This is advantageous in fabrication.

The economic advantages of the continuous casting process are significant, and several typical examples are given. Lead times for press-forged parts are greatly reduced, and the mechanical properties compare favorably with those previously obtained, since there is no directionality, in many instances. Reduction of rolling cost and higher yield are, however, the primary reasons, at least in Germany, for the extensive use this new process enjoys.

Because of the absence of hot tops and because the continuously cast bar is usable over practically its entire length, yields up to 98% have been obtained commercially. Comparative cost breakdowns for various alloys are given as is a detailed analysis of the research program now under way at the author's plant.

It is emphasized that progress in continuous casting is still in its infancy, although production figures have already reached 500 tons per month at one plant.

HANS HEINE

Bridgeport Brass chooses SPEEDOMAX® H CONTROL for vacuum annealing Ti, Zr and special alloys

Bridgeport, Conn.—Vacuum anneal . . . cool . . . then draw! Again and again . . . until the seamless tube of titanium, zirconium or special alloys takes final dimensions.

That's the procedure at Bridgeport Brass Company's Housatonic Plant where reliable Speedomax H temperature control is helping them produce tube after tube of the same high quality.

Quantity production of these tubes requires close control of all variables, particularly atmosphere and temperature.

To minimize loss of the expensive "new" metals and to maintain chemical and physical characteristics, Bridgeport Brass Co. installed a HIVAC vacuum annealing furnace with a Westinghouse heating chamber over a year ago. With evacuation held to 0.01 micron, four Speedomax H instruments provide D.A.T. control . . . constantly regulate power input to hold product temperature well within specifications. Such dependable automatic control is resulting in production savings which make the use of these new metals more economical.

You may not be vacuum annealing . . . but no matter what your heat treat, it'll pay you to investigate Speedomax H. Its workhorse characteristics . . . its two to four week delivery . . . and its moderate price now, more than ever before, make this null-balance controller an attractive investment.

A phone call or letter to your nearest L&N office or to 4927 Stenton Ave., Phila. 44, Pa. will bring more information. Ask for data sheets.

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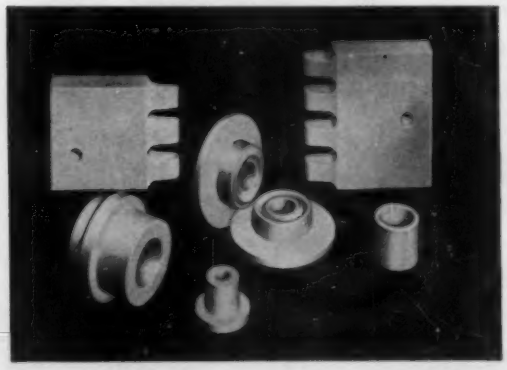

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Materials selected and recommended for compatability with your windings. Send us your specifications and a summary of operating conditions.

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Welding by Electron Beam

Digest of "High-Vacuum Electron-Beam Fusion Welding", by W. L. Wyman, *Welding Research*, Welding Research Council, Vol. 23, February 1958, p. 49-53-s.

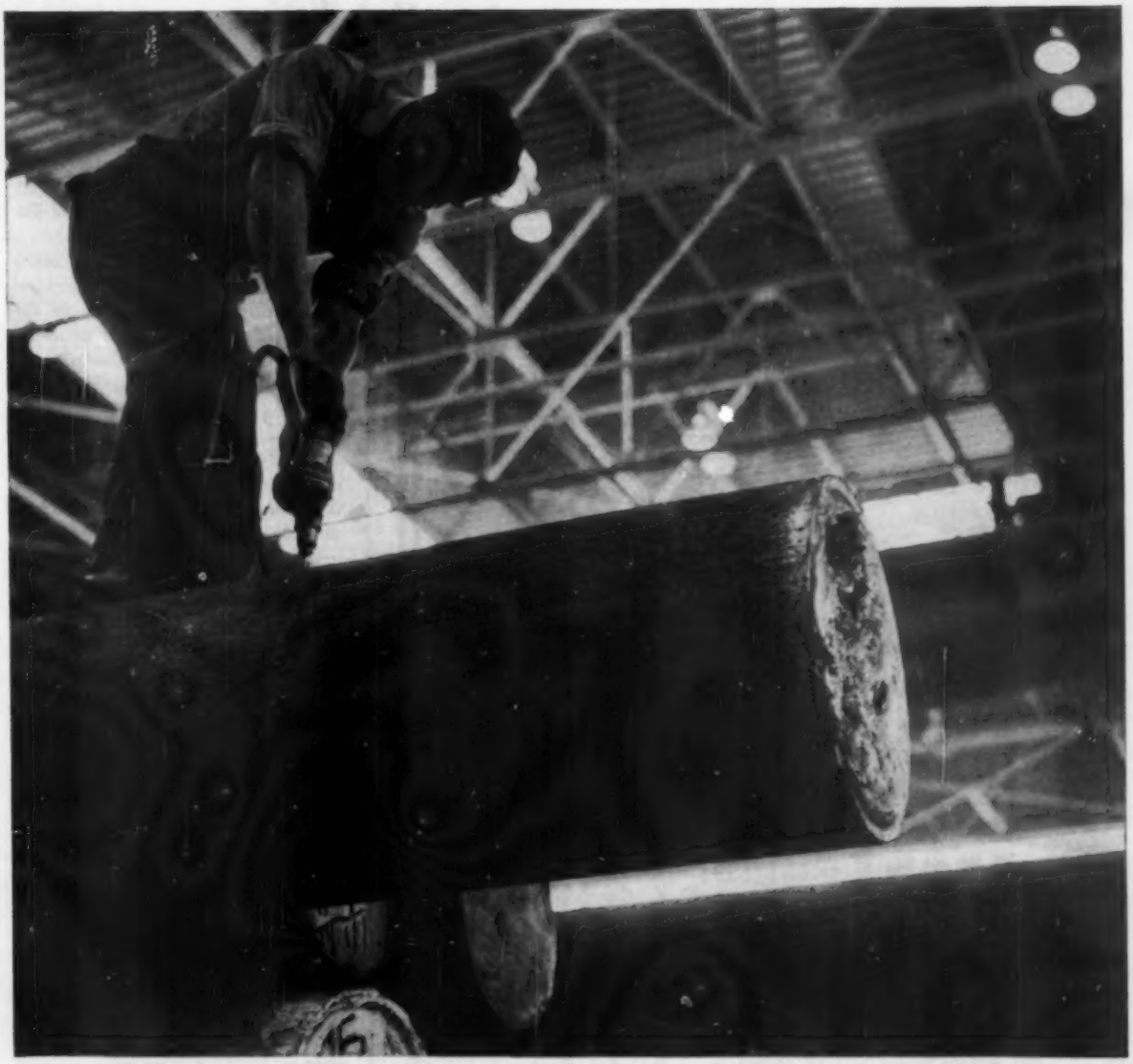
If a current of say 1760 volts or higher potential is passed through a refractory metal wire (tungsten) heating it to incandescence, enormous amounts of electrons (particles of negative electricity) are thrown off the surface at a speed related to the voltage. If this occurs in air, the electrons quickly strike oxygen or nitrogen molecules, ionizing them so the gas becomes a conductor and the electric arc is established.

However, if the equipment is in an evacuated chamber, exhausted to 1 micron (0.001 mm. Hg) or lower, the emitted electrons can be focused with a simple electrostatic field ("lens") so they can hit a small spot on an object below where their kinetic energy reappears as heat. The higher the voltage in the filament the higher the kinetic energy of the electrons in the beam and the greater the energy delivered to the spot – up to a limit of about 15,000 volts whereupon dangerous hard X-rays are generated.

In this new method of welding, dubbed "vacuum weld", the electron gun (source of focused beam) is mounted in a tight chamber at proper distance above a joint to be welded, the latter being held in some traversing mechanism. The equipment has been used for welding plugs in the end of Zircaloy tubes (casings for fuel elements in atomic reactors), and these tubes can be held in a motor-driven rotating system.

Since the welding is automatic, the human element is eliminated. Welding does not start until a sufficient vacuum is achieved, corresponding to an "effective purity" of the atmosphere in the chamber of 99.9999%. (Compare this with the 99.99% He of welding grade or the 99.95% A.) This assures extremely low chance of contamination by oxygen or nitrogen; any ionized molecule would travel toward the cathode rather than to the workpiece. No weld porosity occurs.

The electron beam is "soft" – it



Kaiser Aluminum ingots being prepared for "homogenizing" in Gas-fired furnaces prior to extrusion into aircraft parts

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Gas plays a major role in the development of precision quality alloy extrusions for aircraft at the U. S. Air Force Heavy Press Plant operated by Kaiser Aluminum at Halethorpe, Maryland.

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Again, Gas is used to heat the extruded shapes in a controlled atmosphere to impart the desired physical qualities in the alloys used. As in the melting process, Gas provides precise temperature control and close control of atmosphere within the furnace.

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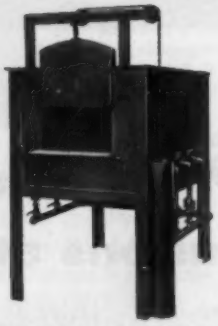

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Welding . . .

exerts no apparent force on the molten puddle and leaves no crater or other stress raiser on the surface. Also there is no tendency to blow the molten metal away from thin material (0.005 in.) being welded. Welds have a smooth mirror-like surface. The only visible effect is the melting of a spot; the beam itself is not detectable. The electrostatic focusing device controls the area of the hot spot; the depth of melting is related to the primary voltage and speed of the traversing mechanism.

While most of the work at Richland with this process has been done on zirconium, successful trials have been made with tungsten, molybdenum, titanium, nickel and their high alloys, stainless and heat resistant steels. Welds in Zircaloy 2 (1.5% Sn, 0.12% Fe, 0.10% Cr, 0.05% Ni), cold rolled 13%, have satisfactory physical properties:

	Vacuum Weld	Base Material
U.T.S.	92,900	96,000
R.A.	39%	36%
Controlled bend	0.5 t	0.4 t
D.P.H. (10 g.)	166	198
Grain size	0.432 mm.	0.016

Welding conditions are: vacuum 0.1 micron, 3900 volts d-c, 22 milliamp. at the power supply, travel 5 in. per min.

As noted the principal change is in hardness and grain size. Welds are not susceptible to corrosion in 685° F. water after 70 days.

In addition to an unusual ability to melt or weld the highly reactive, and refractory metals, the author suggests that research equipment of this sort could well be used to study some fundamental problems in fusion welding, completely free from the masking effects of gas contamination. E.E.T.

Low-Shaft Blast Furnace

Digest of "Low-Shaft Blast Furnace Holds New Promise", by F. W. Starratt, *Journal of Metals*, Vol. 9, November 1957, p. 1432-1434.

THE LOW-SHAFT blast furnace is becoming interesting for locations where small amounts of pig iron are

XXVIII

This is the twenty-eighth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Cold-Finishing of Alloy Steel Bars: Turning and Polishing

Continuing our discussion of the cold-finishing of alloy steel bars, we take up the subject of turning and polishing. A later discussion will cover grinding and polishing. Both require removal of surface metal. In both the turning and grinding operations, adequate allowances provide for the removal of decarburization and surface defects which sometimes occur in alloy bars.

As previously stated, the outstanding advantage of cold-drawn bars over hot-rolled bars is the *bright, smooth finish*. However, the quality of the cold-drawn finish varies with the size and amount of draft (reduction of cross-sectional area) applied in cold-drawing. For example, by using a 1/16-in. draft, a 3/4-in. round would have a better cold-drawn finish than a 3-in. round.

When a superior mirror-like finish with additional accuracy is required on surfaces that are not machined (such as on shafting or machine parts), two processes other than cold-drawing are suggested: turning and polishing, and grinding and polishing. The first of these will be discussed here.

Turning and Polishing. This method of cold-finishing is generally associated with centerless bar-turners, accommodating rounds from 1 1/4-in. to 6-in. diam, inclusive. The process is the reverse of conventional lathe-turning, which is normally used for larger sizes. The centerless turning equipment uses two cutter heads which contain from one to four cutting tools. The system provides for both rough and finish cuts. The bar, which is stationary, is fed horizontally into the rotary cutter heads by means of a mechanical or hydraulic feeding mechanism. Most bar-turners are equipped with a series of polishing rolls that also rotate around the bar as it feeds from the rotary cutter heads. This, combined with subsequent burnishing action from the straightening rolls, imparts a high degree of polished finish to the product. A polished surface on a turned bar can also be produced by a number of passes through the straightening rolls.

This process is applicable to normalized, annealed, or heat-treated carbon and alloy bars. It does not materially affect the mechanical properties. For this reason, the end product can be machined unsymmetrically, with little or no tendency to warp.

Bethlehem metallurgists will gladly work out any problem in the cold-finishing of alloy steel bars. Always feel free to ask for their services.

When you are in need of steels remember, too, that Bethlehem manufactures the entire range of AISI standard alloy grades, as well as special analysis steels and all carbon grades.

If you would like reprints of this series of advertisements, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The subje ts in the series are now available in a handy 40-page booklet, and we shall be glad to send you a free copy.

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PSC
THE PRESSED STEEL CO • Wilkes-Barre, Pa.

Blast Furnace . . .

desirable and where cheap coal and ores are available. The pilot plant making about 15 tons a day has been operating since 1954 in Cologne, Germany. This furnace has an oval section with an area of 1.04 sq.m. (11.2 sq.ft.) between the tuyeres. The charging mechanism maximum height is about 10 ft., although in actual operation the working hearth averages about 9 ft.

This furnace is charged with coal, ore and flux mixed in the form of briquettes and is blown with air instead of oxygen. On the basis of 100 hr. furnace operation out of one operating period of three weeks, bessemer grade iron containing less than 1.5% Si and 0.05% S, about 4.4% C and 1% Mn was obtained. Casting temperatures average about 2460° F. The coal requirements were high on this furnace, averaging about 2.2 metric tons of coal per metric ton of iron produced. Even so, this is less than the coal required for sintering and making blast furnace coke. In a larger furnace it is estimated that the furnace can operate on a maximum of 1.2 metric tons per metric ton of iron produced.

The furnace also produces a gas containing about 30% CO, 3 to 4% CH_4, 3 to 4% CO_2, 8% H_2 and 55% N_2. This has a heating value of about 160 Btu. per cu.ft. Following these results, a 100-ton furnace is now under construction at Troisdorf. This furnace will produce over 100 tons of iron per day and is of a rectangular cross section measuring 16½ × 8¼ ft. at the tuyere level; the height of the charging door is about 16 ft. It is lined with carbon bricks to the tuyere level and normal blast furnace refractories above this point. There are ten tuyeres, four on each side and one on each end. These will supply the furnace with wind heated to 1470° F., considerably higher than in the experimental furnace. The furnace will be blown at about 710,000 cu.ft. per hr. and the blast pressure will be about 7 lb. An interesting feature of this furnace is a recuperator in which the wind blown will be preheated by hot gases, leaving the top of the furnace and burners inside of the alloyed steel pipes while the cold air comes in around the recuperator.

An important part of this plant is

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Somers Brass Company, Inc.

105 Baldwin Ave. Waterbury, Conn.

Blast Furnace . . .

the briquetting plant. Wet ores are fed into three wet bunkers, which discharge into a Humboldt cylinder-type drier, fired by blast furnace gas. The dried material is carried out of the drier by an air current and collected in a cyclone which feeds into the dry bunkers. Material coarser than 10 mm. is not carried out by the air current, but instead it falls into a discharge hopper and is fed into a hammer mill for grinding to −5 mm. Flue dust from the low-shaft furnace is also fed into the bunkers containing dried ore.

The proper mixture of ore, flux, and coal is automatically fed by a conveyer belt into a cylinder-type mixer where it is mixed with ground pitch to form a binder and then into the Humboldt briquetting press, which is similar to presses used for briquetting coal.

The gas cleaning plant is another important part of the furnace layout. From 210,000 to 250,000 cu.ft. of gas per metric ton of iron will be passed through an insulated dust catcher followed by two units with water sprays where tar and dust are collected in the form of mud in the pits beneath. The gas leaving these units at about 1470° F. passed into two disintegrators for tar collectors. The gas containing 2 g. of dust per cu.m. then enters the final cooling unit, in the lower part of which the light oils are separated from the cooling water. It is believed that this type of furnace will have a unique advantage in remote locations and all kinds of ores and coals can be used instead of metallurgical coke.

E. C. WRIGHT

Forgeable Iron-Boron Alloys

Digest of "High-Boron Alloy Steels", by T. H. Middleham, J. R. Rait and E. W. Colbeck, *Journal*, Iron and Steel Institute, Vol. 187, September 1957, p. 1-14.

BEFORE THE ADVENT of nuclear reactors, little interest was shown in high-boron alloy steels because the difficulties of working them were apparently insurmountable and their extreme brittleness rendered them unsuitable for structural or engi-

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Boron Steel . . .

neering uses. Since boron has a very high thermal neutron capture cross section, nuclear engineers became interested in using alloys containing substantial amounts of boron for control rods as well as for general shielding applications in thermal nuclear reactors.

This paper describes a new technique for producing boron-iron alloys, containing up to about 4.75% B, that can be successfully forged, rolled or extruded, and for producing boron-iron alloys containing up to about 6% boron that can be successfully produced in the form of castings.

The most widespread use of boron in steel to date has been in the form of extremely small additions to increase the hardenability of medium and high-carbon low-alloy steels. From a search of the voluminous literature on this subject, the authors have concluded that forgeable iron-boron alloys, containing substantial amounts of boron, have not previously been produced. Since there was no readily available simple test for the assessment of hot workability of high-boron steels, it was necessary to evaluate hot working characteristics by actual forging or rolling of ingots. The initial forging experiment was carried out on a 2% B alloy in the form of 2¼-in. square ingots. It was found possible to forge and roll ingots of 2% B steel in the temperature range 1560 to 1995° F. However, above 2% B the iron-boron alloys proved to be unforgeable. As a result of the present investigation, it was found that upon the addition of aluminum on the order of 4 to 5% to the iron-boron alloys containing up to 4.75% boron, a significant degree of forgeability would be produced.

The largest ingot forged was 9 in. square. Steels with a maximum of 2% B have been successfully forged from 14-in. square ingots. However, the boron content has been limited to 3.8% for large-scale production of steel for rolling or forging. Carbon contents are preferably held to values not greater than 0.10%, since with the higher boron content, increasing carbon content increases the difficulty in forging.

W. W. AUSTIN

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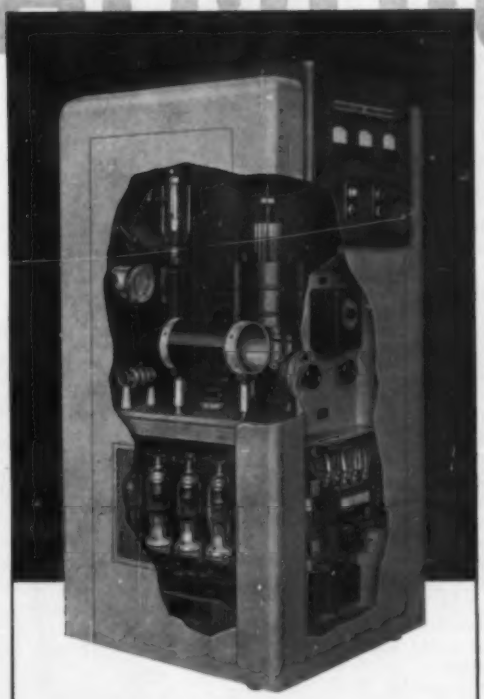

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Class 5. Copper, nickel, zinc, lead and their alloys.

Class 6. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.

Class 7. Metals and alloys not otherwise classified.

Class 8. Series showing transitions or changes during processing.

Class 9. Welds and other joining methods.

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A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters in Cleveland.

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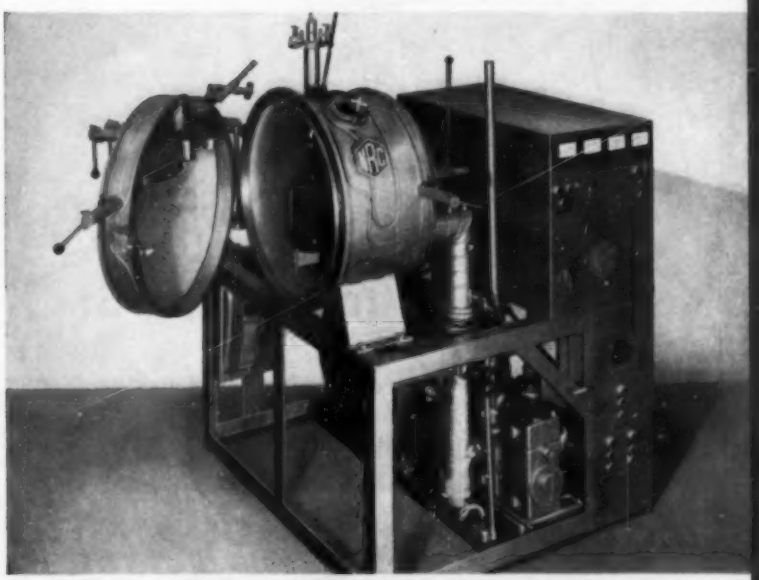

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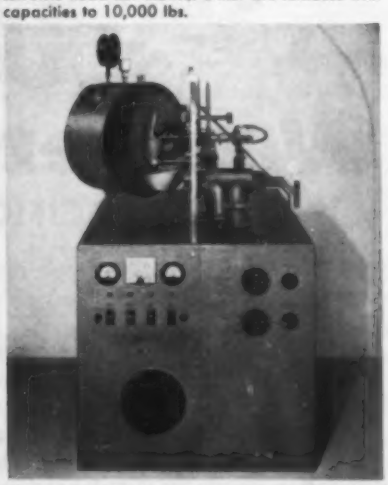

NRC Model 2904-B Vacuum RESISTANCE Furnace. Over 100 now in use for melting, purifying, alloying, casting, sintering, brazing, annealing, and heat treating. Capacity 2-8 lbs. Temperature above 2000°C. Pressures to 10^{-5} mm Hg. Other standard resistance bell, muffle, and pit furnaces with hot zones to 54" dia. by 12'.

If you're considering vacuum metallurgy as part of your product improvement or quality control program, you don't have to start from scratch. You can get a head-start by drawing on the experience NRC has gained from building and operating more high vacuum furnaces than any other organization in the world. You can easily find out

If vacuum metallurgy can help you as it has others.
Whether you really need to run your own development program.
What type of furnace would be most suitable for your program.
How to avoid the expensive pitfalls which have so often trapped beginners.

Then, if you decide to run your own development program, you'll find you can get started easily, economically and quickly with a standard NRC furnace, such as those shown here. You won't need a vacuum expert to run it either. NRC furnaces are designed for simplicity, and our engineers will teach you up-to-date operating techniques. This is the way for you to get useful results sooner, with a minimum investment in equipment, time, and operating costs.

Get started easily by writing for more information today.

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A Subsidiary of National Research Corporation

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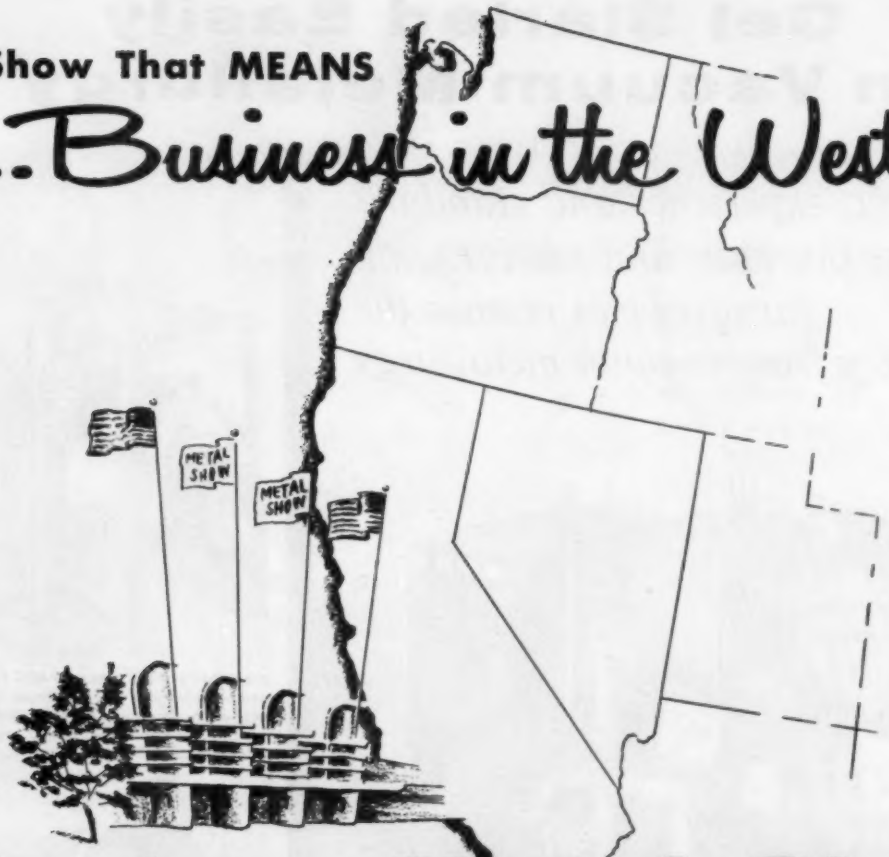
...Business in the West!



Western Metal Show

PAN-PACIFIC AUDITORIUM • LOS ANGELES

MARCH 16-20, 1959

During the past quarter-century of flourishing growth of industry in the West, one exposition pioneered and grew with this record-breaking western progress — the Western Metal Show.

Continuing to keep pace with these great western industrial markets, the 11th Western Metal Show will open next March 16 in Pan-Pacific Auditorium. Hundreds of the nation's leading firms will go west once again to present their metals, their equipment, their processes and their improved and new products.

This great metals week of the West will not only present what's new and improved . . . it will be a proving ground for scores of new developments presented in technical and practical engineering sessions sponsored by the American Society for Metals and 20 cooperating societies and associations. Thousands of metal men will have every reason to attend this outstanding event.

Floor plans for this 11th western show are now available. Make certain you have your copy . . . that you select your exhibit space . . . that you make your plans to exhibit in the show that will *mean business for you* in the West.

• • •

WESTERN METAL CONGRESS & EXPOSITION

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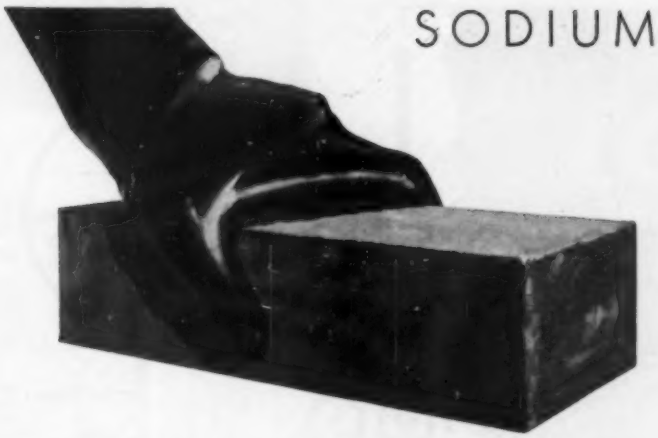
AMERICAN SOCIETY FOR METALS

7301 Euclid Avenue • Cleveland 3, Ohio

SODIUM ALLOYS



put SODIUM to work for YOU!

Sodium is easily alloyed with many metals. Selection and proportion of the alloying material are factors giving wide control of sodium's performance.

Sodium can be hardened through alloying for better flaking or pulverizing. By leaching out sodium from the alloy, it can supply other metals in sponge or porous forms for catalysis and other contact uses. It is also an effective wetting agent for the application of aluminum and zinc.

Sodium will reduce many metal halides to the virgin metal. Modification of aluminum silicon alloys with sodium is effective for uniform distribution of silicon.

High boiling point, excellent wetting of heat-transfer surfaces, and freedom from carbonization, polymerization, or decomposition, characterize sodium and sodium alloys in heat-transfer applications.

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- ☐ Fact Sheet on Sodium Alloys
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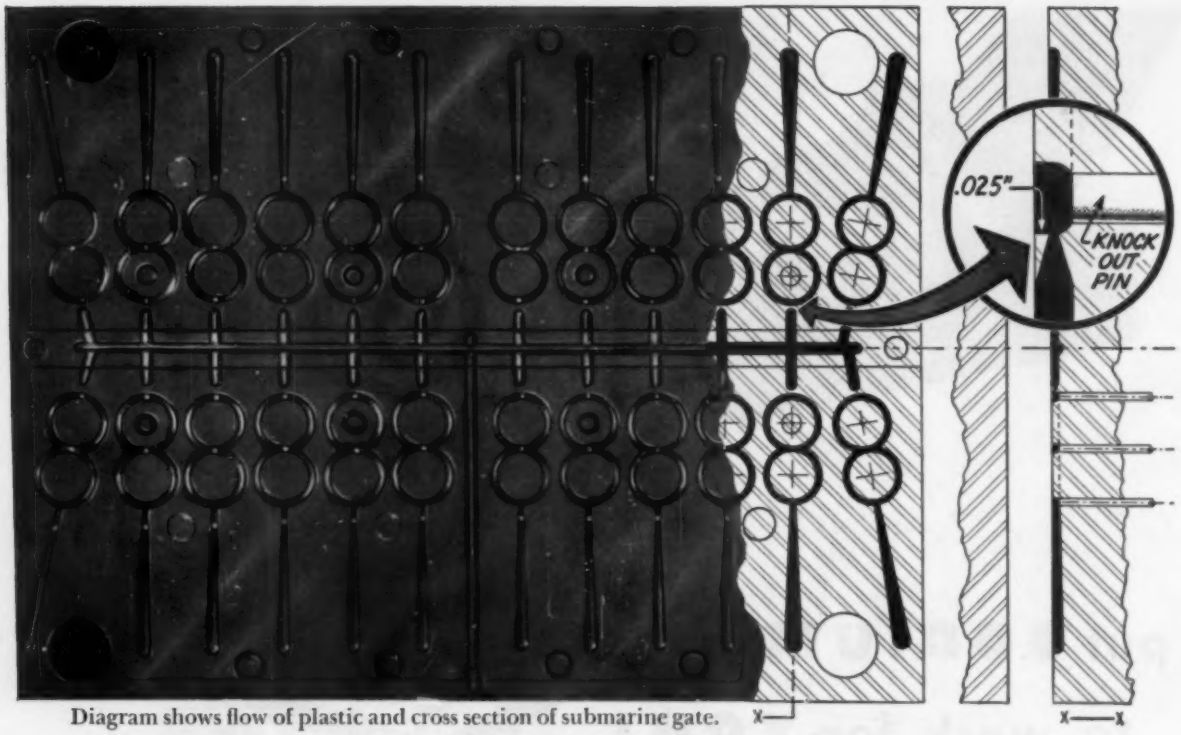

Diagram shows flow of plastic and cross section of submarine gate.

How Much Dimensional Stability Can You Demand From A Tool Steel?

Plenty, Case History Of UDDEHOLM's UHB-151 Shows

Just how much dimensional stability *can* you ask from a tool steel without risking injury to your investment? Quite a bit, actually, *depending on your choice of tool steel.* In the injection mold illustrated above Uddeholm's air-hardening UHB-151 gave a remarkable example of such stability. Any excess movement of the steel during hardening would have ruined the mold. Edge-fed, with 24 cavities, this mold produces styrene plastic "bubble wand" prizes for children. Each cavity has three knock-out pins—a total of 72. These pins must fit a .093" diameter hole snugly enough to prevent flashing, yet cannot bind. Tolerance for depth of cavities across corners of blocks was only ±.00025"! The submarine gates, also drilled before hardening, were just .025" off cavity edge—leaving a tiny triangle of steel supported by only that thickness.

Utmost safety in hardening was needed to prevent the small submarine gate piece from cracking—and to hold the knock-out pin holes to required tolerance. Excellent non-deformity was needed to assure perfect meeting of the two die halves. Perfection Plastic Engineering Co., of Philadelphia, maker and user of the die, chose Uddeholm's UHB-151 to do the job.

Among Uddeholm's wide selection of fine, Swedish-quality tool steels you can always find one to meet your specific demands. And each Uddeholm sales representative is a tool steel specialist. You can always depend on him to recommend the tool steel best suited to your job. Call on him whenever you need tool steel service or information.

Write For Tool Steel Stock List No. 12

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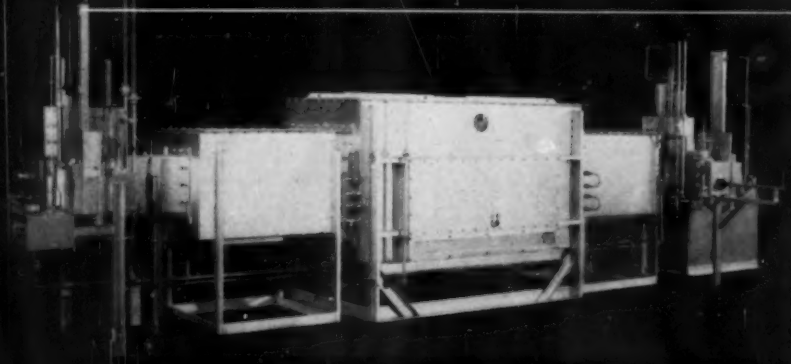
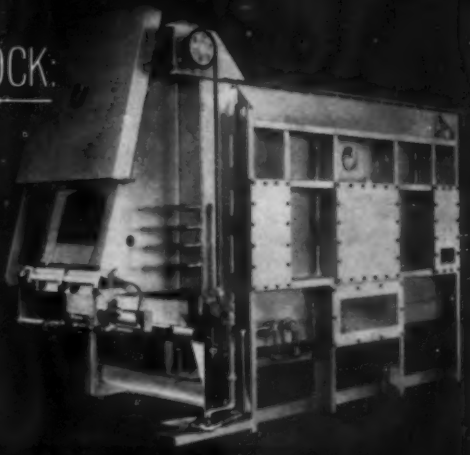
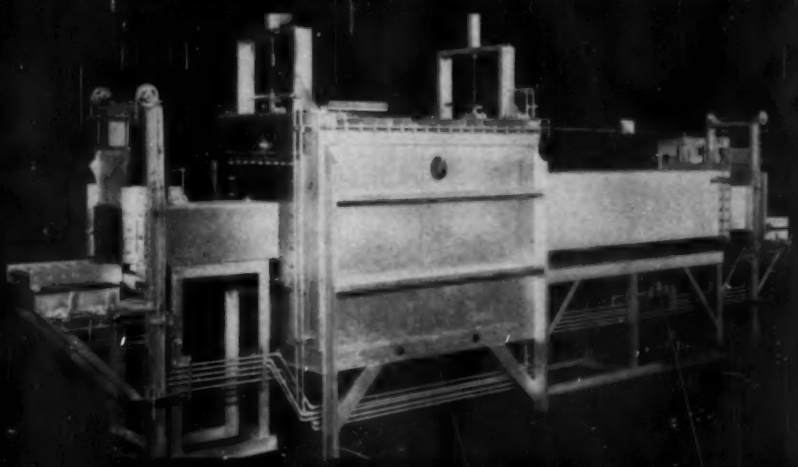


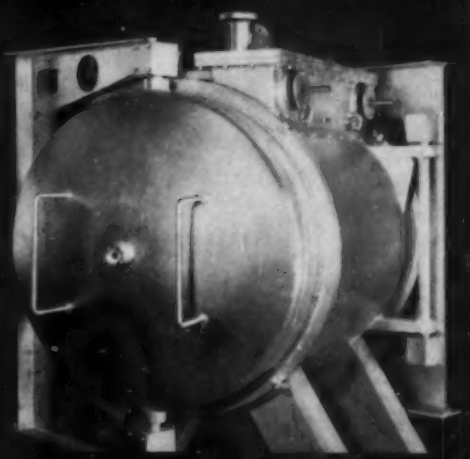
Sintering as many as 1250 UO_2 fuel pellets per hour in a hydrogen atmosphere, this Harper continuous pusher furnace is equipped for semi-automatic operation at temperatures up to 1750°C. Designed for gradual heating and cooling, furnace has rugged moly heating elements, pressure relief vents, entrance and exit purge chambers.



Operating at temperatures as high as 1600°C, this single-ended batch furnace heats moly billets (up to 110 lbs./hr.) in a hydrogen atmosphere. Equipped with moly elements, it has two zones of heat control.



Sintering tungsten alloys (up to 75 lbs./hr.) in an atmosphere of dissociated ammonia, this moly furnace operates at temperatures as high as 1500°C. Designed for quick transfer from hot zone to cooling zone in atmosphere, it is equipped with pneumatically lifted refractory baffle doors for temperature uniformity.



Sintering stainless steel and tungsten powder parts at temperatures up to 2000°C, this Harper moly box furnace operates with mixtures of inert and reducing atmosphere gases.

MOLY FURNACES SUCCESSFUL UP TO 2000°C

As furnace operating temperatures rise above 1300°C (2350°F approx.), problems multiply. For example:

- What is the best combination of atmosphere and heating elements to obtain results desired?
- What refractories will prove most practicable from the standpoint of process, economy and service?
- Are purge chambers desirable or necessary?
- How should purge chamber doors be built to insure atmosphere-tight operation?
- When should automatic gas purging and automatic door sequence control be provided for quality, safety and economy?
- How should refractory baffle doors, roofs and hearths be constructed?

It takes experience to come up with the most profitable answers to questions like these in any given situation . . . *and Harper has experience to spare.* The four molybdenum heated units pictured above are but a few of many furnaces that have been built by Harper for high temperature applications. Among others are graphite tube models which perform with creditable success at 2750°C (5000°F approx.).

No matter what type of furnace you have in mind — box, pusher, mesh belt, roller hearth, bell, elevator or pit — Harper can supply it to operate most advantageously both temperature-wise and dollar-wise.

For more information, talk to your Harper representative or write: Harper Electric Furnace Corporation, 40 River Street, Buffalo 2, N. Y.

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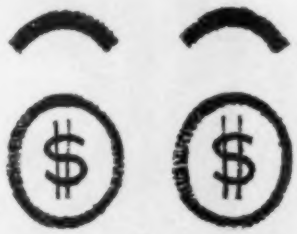
FOR BRAZING, SINTERING, WIRE ANNEALING, BRIGHT ANNEALING, FORGING AND RESEARCH



February—Bought lower grade ammonia at a bargain price . . .

Later—Discoloration of finished parts apparent, rejects more frequent, pickling necessary . . .

Still later—Oil! Pressure regulators clogged, catalyst poisoned, incomplete dissociation . . .

Too late—Shut down metal treating line for repairs . . .

Be trouble-free—use only Armour's 99.98% pure ammonia in your metal treating operation!

Such consistent purity, dependable delivery service from 163 stock points and 8 bulk stations—and a technical service that's second to none—make Armour your one best source for trouble-free ammonia. For further information and a copy of the informative Dissociated Ammonia booklet, write us on your company letterhead.

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Of course you can titrate NIALK® TRICHLOR but you never have to

psp is why • The reason you take the time and the trouble to titrate your degreasing solvent is to make sure its stabilizer is still active.

Users of Nialk trichlorethylene find six good reasons why they never *have to* titrate. All six add up to *psp*—permanent staying power.

psp means neutral The neutral Nialk stabilizer cannot react with acids to form corrosive salts. Yet it will "accept" acids and render them neutral and harmless.

psp means insoluble in water You never lose the Nialk stabilizer during steam distillation or in the water separator of your degreaser.

psp means full protection The Nialk stabilizer has the same boiling point as the solvent, so you get complete recovery during distillation and full protection in your degreaser's vapor phase.

psp means no staining or discoloration of parts There are never compounds present which can cause staining or deposit formation on the metals you degrease.

psp means clean bath and coils Nialk trichlor eliminates those deposits on coils which cut down heat transfer. Nialk baths have gone for long periods of time without coil cleaning.

psp works with all metals Even white metals are degreased safely with Nialk. Chlorides of these metals, which might be formed under unusually severe conditions, are rendered harmless by the Nialk stabilizer.

Hooker Bulletin 70 gives a complete study of stabilizers. Bulletin 72 offers a standard titration method for Nialk trichlorethylene. Send the coupon for either.

Please send: ☐ Bulletin 70, Advantages of Nialk Neutrally Stabilized Trichlorethylene ☐ Bulletin 72, Acid Acceptance Test for Trichlorethylene.

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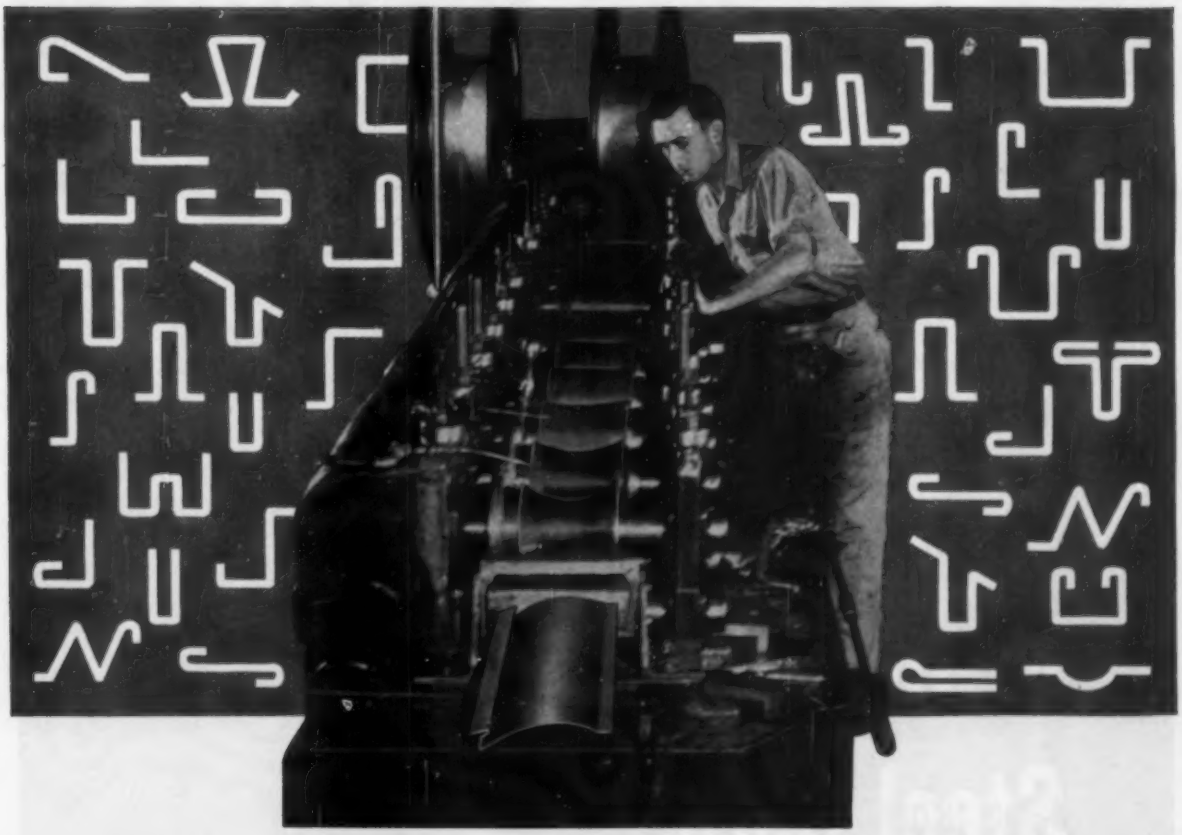
If you have to titrate your degreasing solvent often because it contains stabilizers which wear out, it's time you took a look at Nialk TRICHLORethylene with psp.



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COLD ROLL FORMING MACHINES
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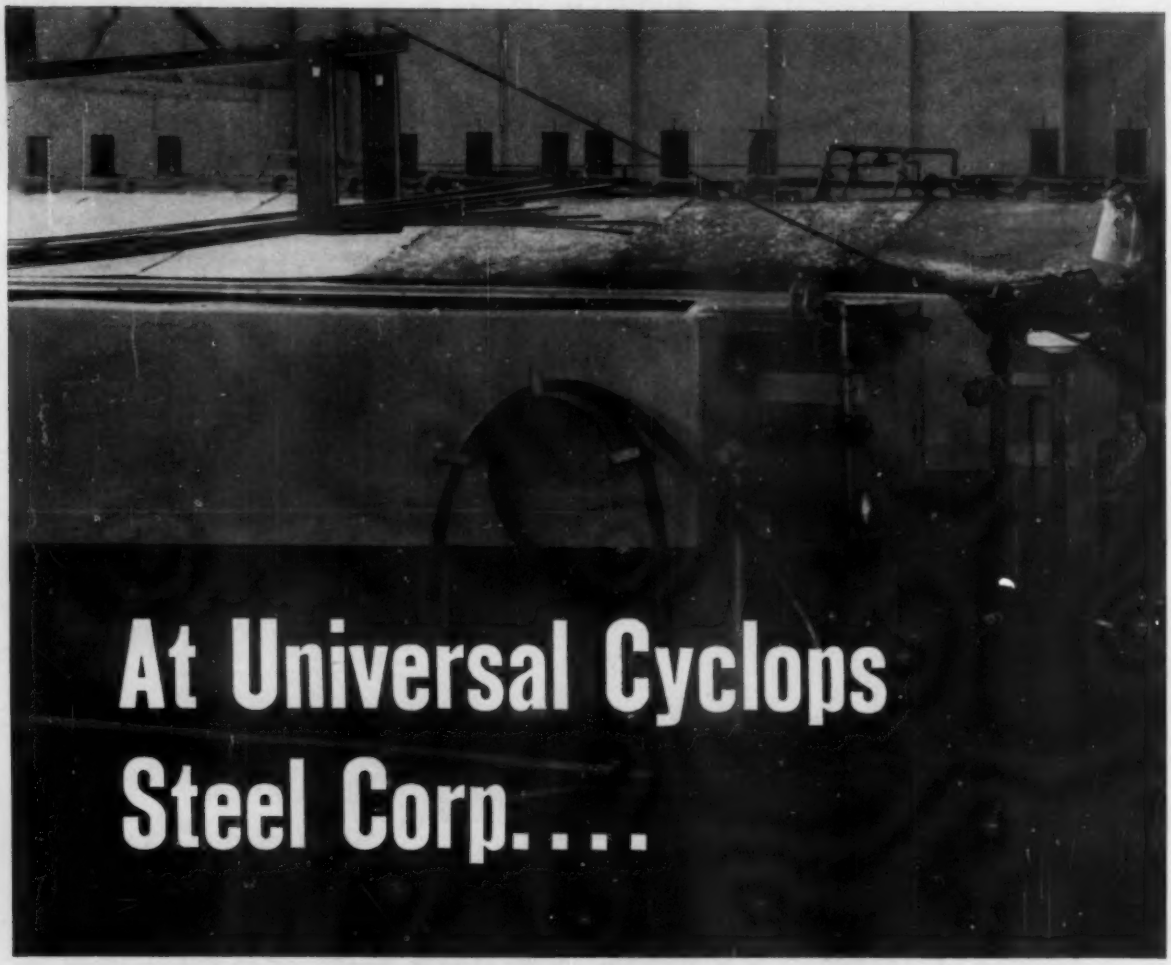
ROTARY SLITTING LINES



At Universal Cyclops Steel Corp....

A third Du Pont Sodium Hydride unit efficiently descales bar products without pitting or etching

After several years of success with two Du Pont Sodium Hydride units at their Bridgeville, Pa., plant, Universal Cyclops is now operating a new unit in Titusville, Pa. Here they are completely descaling hard-to-clean stainless- and tool-steel bars in 20 minutes or less.

Du Pont's Sodium Hydride Process can give you ideal descaling results: *a lustrous pearly-gray finish with no etching or pitting!*

Any metal unaffected by fused caustic at 700°F. can be quickly descaled by the Du Pont Process, and there's never any loss of gauge. Costwise: substantial savings in acids and waste disposal. We'll be glad to give you all the facts on the Du Pont Sodium Hydride Process. Just drop us a line at the address below.

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Model RSZ503 Rivet Cooler (shown) equipped with 90 rivet canisters, temperatures to –30° F. 110V, 60 cycle, single phase.

Model SZH153 with temperatures to –95° F. 110V; 60 cycle, single phase.

Model SZH653, larger capacity, temperatures to –85° F. 110V, 60 cycle, single phase.

Model SZHC657. Same capacity as SZH653 but attains temperature as low as –140° F. 220V, 60 cycle, single phase.

Refrigeration: Model SZHC657 operates with 3 Tecumseh hermetic compressors in a two system cascade. Other Sub-Zeros use 2 hermetics in a two stage system. Rivet Cooler operates with single hermetic unit. All models equipped with efficient fan-cooled condensers—no liquid coolant required. *Write Today for Full Specifications and Prices.*

Description	Model	Cu.Ft.	Temp. Range		Outside Dim.			Inside Dim.		
			Rm. 70°	Rm. 110°	L	W	H	L	W	H
Sub-Zero	SZH153	1.5	–95° F.	–85° F.	42"	28"	42¼"	23"	9"	12½"
Sub-Zero	SZH653	6.5	–85° F.	–75° F.	60"	28"	42¼"	47"	15"	16"
Sub-Zero	SZHC657	6.5	–140° F.	–125° F.	60"	28"	42¼"	47"	15"	16"
Rivet Cooler	RSZ503	5.0	–30° F.	–20° F.	42"	28"	41"	30"	16"	18"

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Specifications: setting space 7" wide by 9" deep by 8½" high . . . outside dimensions 23" wide by 28" deep by 64" high. 3000° F. internal refractories. External blower for accelerated cooling. 8 KVA transformer, voltage adjustable from 55 to 230 volts in 36 steps. **Price:** $1,240.00 f.o.b. Columbus, including crating.

Other Models with setting spaces up to 36" by 40" by 36" . . . all models with standard or optional instrumentation.

Special furnace designs developed to meet your need. For non-obligating recommendation, send information on materials, temperature range, heat control and firing objectives to Dr. Robert A. Schoenlaub, Technical Advisor.

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Seminar on

RESIDUAL STRESSES

What Are They?

How Do They Get There?

Are They Dangerous?

How Can You Get Rid of Them?

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Prof. R. Weck of Cambridge University and Director of the British Welding Research Association, will be brought to America this October to deliver seven important lectures on residual stresses. Coupled with these outstanding lectures will be seven discussion periods by 14 American experts.

This Seminar will be held during the latter part of Metal Show Week.

October 30, 31 and November 1, 1958

Place: **Wade Park Manor, Cleveland**

Registration Fee: **Including outline notebook, complete printed transcript of proceedings, lunches and dinners for the three days, $150.00 (Early registration with $25 deposit suggested.)**

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American Society for Metals

Metallurgical Seminar Division

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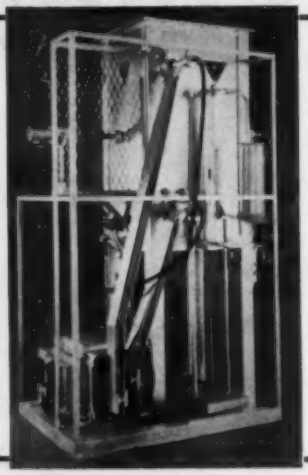
Carbon Resistor Type
VERTICAL TUBE FURNACE

Precision Control at 5000°F. plus or minus 20°F.



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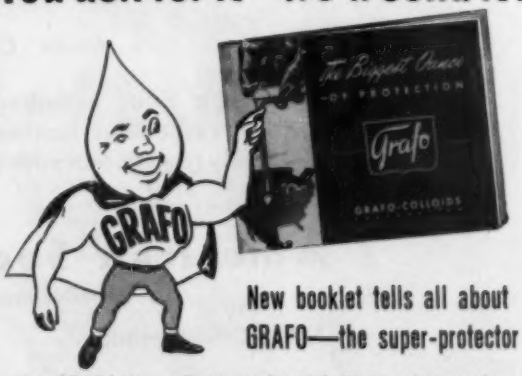

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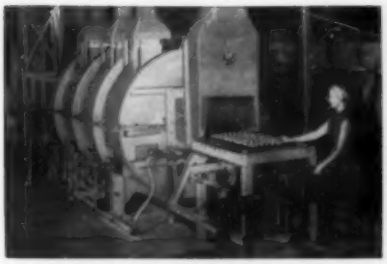

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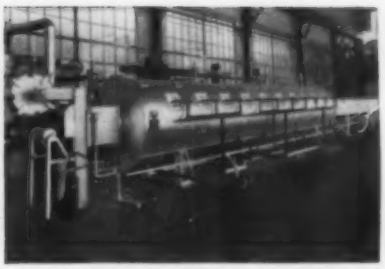

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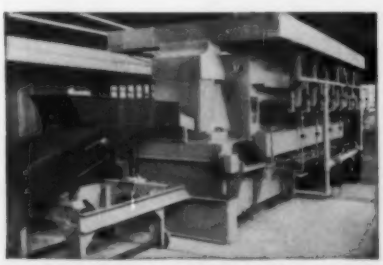

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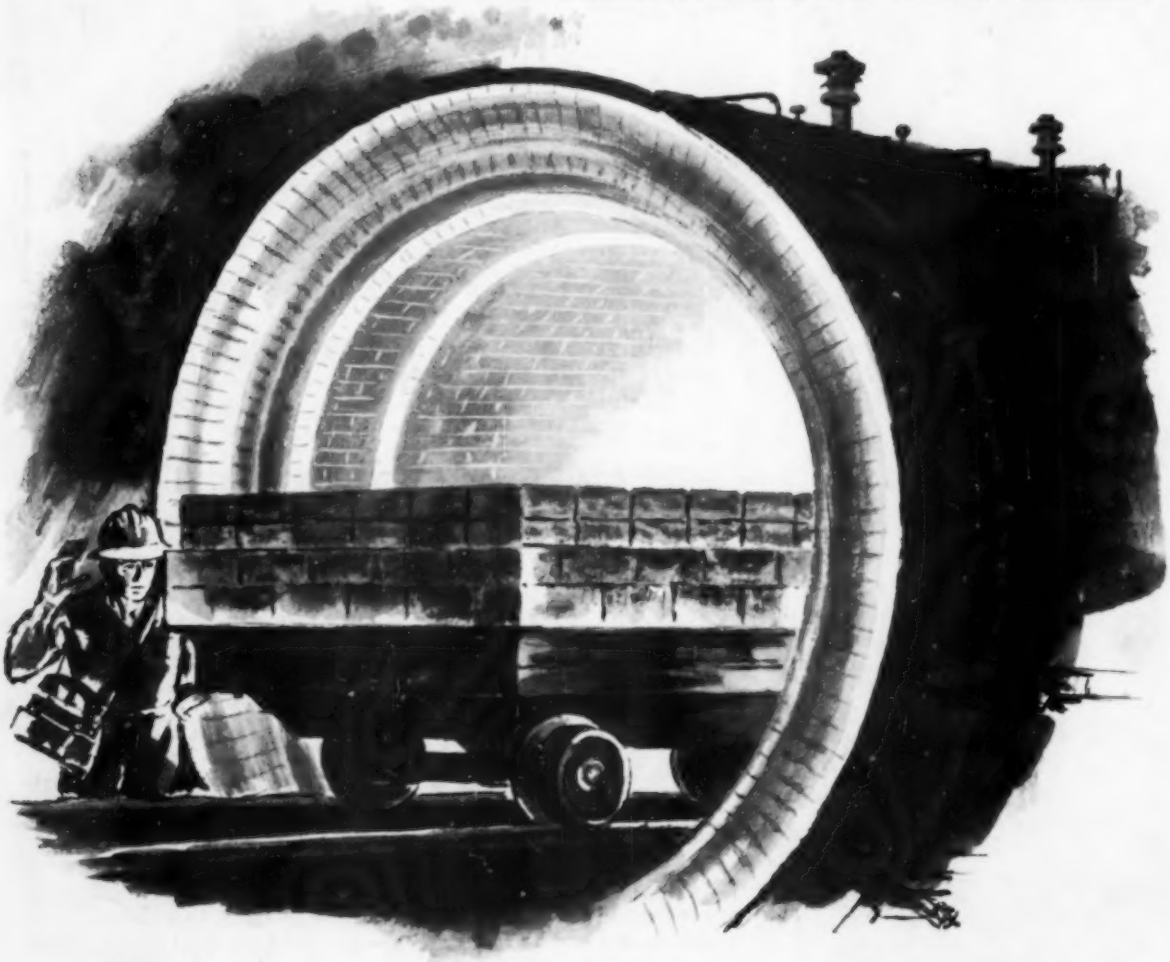

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